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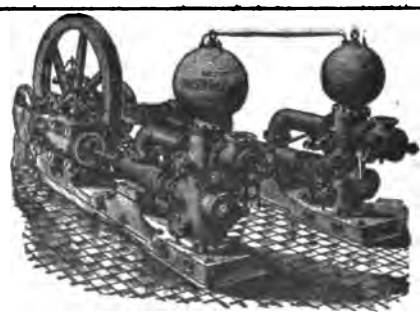

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THE THEORY AND DESIGN OF THE MASONRY ARCH.*

By WM. H. BURR.

INTRODUCTORY.

In his Applied Mechanics Rankine gives to the theory of the masonry arch a masterly treatment worthy of the greatest analyist engineering science has yet known. At the same time his methods are not quite complete for all practical purposes, nor is the equational analysis so well adapted to all arch curves and systems of loading as the graphical. One great merit of Rankine's treatment lies in his recognition of the conjugate (usually horizontal) pressure exerted by the spandril masonry or backing against the ring stones. That pressure exercises a most important influence on the stability of the arch which was essentially if not quite neglected prior to Rankine's time.

No treatment of the arch which is based on the neglect of this conjugate pressure can be considered more than a very loose approximation, for the conjugate intensity at a given point may in some cases exceed that of the vertical loading; while in all arches, unless very flat, it attains a considerable value in the vicinity of the springing joint. A treatment, therefore, which neglects an important element of such magnitude cannot be considered satisfactory.

* Some of the main features of this theory of the arch were first published in Selected Papers of the Rensselaer Society of Engineers for the year 1881. It is here set forth with material changes, improvements and additions.

It is true that the omission of the conjugate pressure involves, in a design for an ordinary arch, an increased degree of stability; but it is equally true that that degree of stability, in some cases, is so excessive that it is not secured. In such cases the line of resistance, as constructed, passes even outside of the arch ring itself. The difficulty is sometimes obviated by making the spandril filling of solid masonry for some distance above the skew-back, although that plan necessitates an extravagant amount of masonry. In other cases the arches continue to stand with no evident sign of insecurity, though such a condition of things is directly in contradiction to the results given by the treatment.

A proper consideration of existing influences will not demonstrate the instability of a strucuure which stands with every evidence of security.

In the treatment of stability which follows, the ring stones will be considered to be unchangeable in shape. This hypothesis eliminates from the question all consideration of the condition of the ends of the arch at the skew-backs, and is not only admissible, but necessary, as the nearest approach to the actual condition of things. There is probably no arch in existence in which perfect continuity from skew-back to skew-back has been preserved after the removal of the centres. If the arch is assumed to be elastic and fixed at the ends, continuity must not only be absolutely perfect and extend through the skew-backs, but the whole structure must settle uniformly, so that the assumed conditions may not be disturbed. The elastic yielding of the abutments is sufficient in itself to modify materially any assumptions that may be made as to constraint in any degree of the ends of a masonry arch, and the settlement of the foundations will usually do far more toward the derangement of those assumptions. If the ends are assumed to be hinged, continuity must hold between the skew-backs, and uniform settlement must take place. In consequence of the number of joints which are observed to open in many existing arches, even upon hasty examination, it is in the highest degree probable that neither perfect continuity nor perfectly uniform settlement occurs in any case.

For these reasons it is advisable if not imperative to make the problem one of pure statics instead of combined statics and strains. These observations as to the masonry arch do not in any way militate against the applicatiou of the resulting theory to those

arch rings in which special devices are used to secure joints at the skew-backs and crowns, as in some excellent modern German structures. Those devices simply insure the passage of the line of resistance through known points, and the theory to be developed is directly applicable to such conditions.

It is supposed that no special devices, such as metallic clamps, are used to bind together the ring stones. With such appliances continuity and some attendant conditions might at least approximately be attained.

It is also to be assumed that no such devices are used to secure the ring stones to the spandril walls or filling. For the reasons already given, then, all forces acting on the arch ring must be directed inward, or, in other words, they must be pressures. The cement joint or joints between the ring stones and spandril can not be considered capable of resisting tension. It is not implied that good hydraulic cement mortar cannot resist tension; but it is true that if a mortar joint in an arch is capable of resisting any tension at all it is impossible to determine to what extent it can be relied upon in that capacity; and in some joints, in good work, even contact does not exist at all points. The real condition of things for a masonry arch will be more nearly described, therefore, by assuming that the arch ring is subject to pressures only. It then becomes necessary to determine just what those pressures are.

ART. 1.—VERTICAL LOADING. The vertical loading of an arch consists of two parts: the fixed, or permanent, load and the moving load. The fixed load includes the spandril filling, or backing, on which the moving load and a part of the permanent load is applied, and which rests directly on the ring stones. The arch ring, therefore, must receive all pressure from and through the spandril,

ART. 2.—RESULTANT PRESSURES ON RING STONES. The resultant pressure on the arch ring may be decomposed into two parts, one of which is the vertical loading, and the other is called the "conjugate" pressure. In many cases, perhaps the majority, this conjugate pressure is horizontal, but in others it is not. In Fig. 1, if the backing *BDC* and *CEF* is composed of dry earth, of which *BE* is the trace of the plane upper surface, it is known, from the theory of earth pressure, that the conjucture pressures h_1, h_2, h_3, etc., against the different ring stones will be parallel to that upper surface *BE*. The resultant pressure against any stone, as *K*, will be that force whose components are h_2, and the vertical load com-

prised between the two vertical lines v and v' drawn from the joints between K and the two adjacent stones, combined with the weight of the stone itself. In other words, the vertical load is simply the weight resting upon the stone in question, and this is to be added to that of the stone itself. The weight is a fixed quantity depending upon the loading; but the conjugate pressure (as h_2) *may have any value between the conjugate pressure of earth loaded, with its own weight only, and the abutting power of earth.* This is a principle of great importance, and it will be seen to have a material influence on the determination of the line of resistance.

Any conjugate pressure (as h_3) on the posterior surface of a ring stone is simply *the conjugate earth pressure exerted on that portion of a vertical plane included between two conjugate planes drawn through the upper extremities* (*as a and b*) *of the two bounding joints.*

These methods of determining the components of the resultant force acting on any stone are very simple and very important. In the figure $a\ c$ is vertical and $b\ c$ parallel to BE, but the methods just given are in no manner dependent upon those directions.

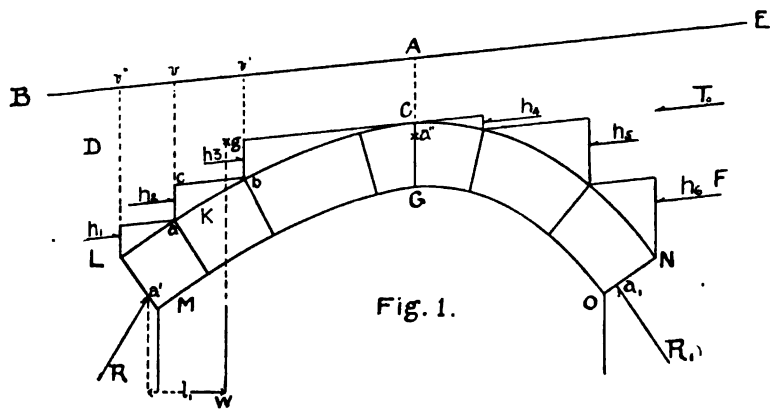


Fig. 1.

ART. 3.—MASONRY BACKING. If the backing BDC and GEF, Fig. 1, is of masonry or any other tenacious material, the direction of the conjugate pressure cannot be determined; it will depend upon the nature of the material, character of work, etc. It may be parallel to the conjugate direction BE, but it will probably not be.

These conjugate pressures may, therefore, in this case be assumed to have any directions whatever which will give a line of resistance most favorable to stability, since this line of resistance may at least be supposed to exist at the instant before rupture. It is implied, of

course, that the obliquities of these pressures, in reference to the surfaces on which they act, must not exceed the limiting angles of friction (the angles of repose) for those surfaces.

In regard to the magnitudes of these pressures, they may have any values which will cause their greatest intensities to lie between the limits of zero and the working resistance to compression of either the backing or ring stones. The upper limit of the intensity will be the least of the two working resistances. If it were a mere question of statics, aside from the consideration of a safety factor, "ultimate resistance" would be used instead of "working resistance."

Thus, within certain limits, there is a capacity of adjustment, requisite to the conditions of stability, of the pressures h between the ring stones and backing.

It should be observed at this point that, if the backing is of good masonry and well bonded to the ring stones, the line of resistance may be located anywhere, within safe limits, between the upper surface of the backing and the soffit of the arch. In such a case questions in regard to stability can hardly arise; it (stability) is secured almost *a priori*.

ART. 4.—RESULTANT PRESSURES OR EXTERNAL FORCES. There have, then, thus far, been shown the methods for finding the vertical and other component of the resultant pressure on each stone of the arch ring; and it is to be carefully remembered that this resultant includes the weight of the stone itself. These resultant pressures are simply the external forces acting upon the individual stones; and they are completely known, for when the character of the pressures h_1, h_2, etc., is once determined, their centers are easily found by known means. The lines of action of the vertical loading and weight, for each stone, are always known.

ART. 5.—GENERAL METHODS OF DETERMINING A LINE OF RESISTANCE FOR THE ARCH RING. When the resultant forces external to the ring stones are known, a line of resistance, or, indeed, any number of them, may at once be drawn. In the older treatments of the arch it was customary to employ what was known as "the principle of least resistance." The "active" forces, as they were called, are the resultants on the ring stones, including the weights of the latter, and they were usually vertical in direction, as the conjugate pressures were ignored. The horizontal pressure or thrust at the crown and springing joints which, with the same sys-

tem of vertical loads, may vary indefinitely with different lines of resistance or polygonal frames was considered to be and was called a "passive" force, as it is dependent upon and called into existance by the vertical or active forces. Since this passive force or thrust may, consistently with equilibrium, vary indefinitely it was necessary to determine at least its probable value. It was, therefore, postulated as being reasonable that the passive force or thrust should have the least possible value consistent with the conditions of equilibrium. Among other things these conditions of equilibrium will depend on the greatest allowed intensity of pressure in the ring stones. This method will be illustrated in the Arts. which immediately follow.

The other method of treatment, which is more convenient for general cases of loading, including that of conjugate pressures, makes no use of the principle of least resistance. Three points are assumed (usually one at each springing joint and one at the crown) through which a line of resistance or polygonal frame for the actual forces external to the ring stones is made to pass. If the line of resistance so determined lies within the prescribed safe limits of each joint throughout the arch ring the arch may be, and is assumed to be, stable, even though the constructed line of resistance be not the true one. If this trial line of resistance does not lie within the prescribed limits for all the joints it must be varied by changing, so far as they may be changed, the variable elements of the problem, such as conjugate earth pressures and the pole distance of the force polygon, at the same time remembering that the assumed points in the line of resistance at the springing joints and crown will one or all be changed. By this method it may readily be determined whether a given arch carrying a given system of loading is stable or not. This method will be illustrated by two actual arch constructions.

ART. 6.—METHOD OF PRINCIPLE OF LEAST RESISTANCE. Let any portion of the arch, *CLMG*, Fig. 1, be considered. If all the external forces acting on this portion were completely known, a trial line of resistance could at once be constructed; but even if the external forces acting on the stones are given, those which act in the joints *CG* and *LM* are still unknown, both in magnitude and line of action. It is known from the first principles of statics, and shown graphically by the force polygon, that if all the forces in a balanced system, except two, are known, *any two which*

will close the polygon will hold the system in equilibrium, provided that the resultant moment of the whole system about any axis normal to its plane (in the arch all forces may be taken to lie in one plane) is equal to zero. From these considerations it at once follows that any one point in each of the joints LM and CG may be assumed as the centers of resistance for those joints, or, what is the same thing, as the points of application of the resultant forces acting on those joints. Let a' and a'', Fig. 1, be those assumed points.

The magnitudes and directions of the forces acting in LM and CG, or through a' and a'', still remain to be found, and the direction of one of them may be assumed. The direction of the one acting through a'' will be assumed parallel to BE and it will be called T_0; the line representing it is removed to one side for the purpose of avoiding complication in the diagram. By taking the moments of T_0 and the resultant external forces acting on the ring stones about the point a', the magnitude of T_0 can at once be found. The remaining force, R, acting in the joint LM becomes immediately determinate, both in direction and magnitude, and can be found by the use of the force polygon. These operations will be carried through in detail, by means of equations or diagrams.

The two forces T_0 and R, which have just been determined, are but one of an indefinite number of pairs which may be used to complete the equilibrium of the portion $CLMG$. The remainder of the problem consists in determining which of all these pairs will probably exist in any given case. The complete solution of this question is perhaps impossible, but an approach to it, at least, may be made. The force or thrust T_0 is either partially or wholly a passive force called into action by the resultant external forces acting on the ring stones, which play the part of active forces.

By the principle of least resistance this passive force T_0 must be the least possible consistent with the stability of the structure.

The least value of T_0 consistent with stabllity can scarcely be found, because the operation by which it is sought is a tentative one. When once the point a' and direction of T_0 are assumed (which assumptions have been shown to be consistent with equilibrium), however approximately, the corresponding value of T_0 is not difficult to fix.

In Fig. 1, let g be the center of gravity of the portion of

the arch Av'' LMG and its load, and let W represent the weight which acts through that point, while l_1, as shown, is the horizontal distance of the line of action of W from the center of resistance a'. Let h represent any of the forces h_1, h_2, h_3, etc. (for the sake of generality these are considered not to be parallel), and let l be the normal distance from the line of action of h to a_1, then the sum of all the moments of the forces h about a' will be Σhl. By taking moments, therefore, about a' there will result:

$$T_0 y_1 = Wl_1 + \Sigma hl \qquad (1)$$

$$\therefore T_0 = \frac{Wl_1 + \Sigma hl}{y_1} \qquad (2)$$

In Eq. (2) y_1 is the lever arm of the thrust T_0, or, the normal distance of its line of action from a', whatever may be the direction of T_0.

If the stability of position of any joint is secured, the center of resistance must not depart farther from the the center of figure than a certain safe distance. Denoting the thickness or depth of the springing joint LM by t, the limiting distance of a' from the center of LM will be indicated by qt. The distance Ma' will be taken as $\frac{1}{2}t - qt = t(\frac{1}{2} - q)$. This assumption fixes the location of a', but leaves that of a'' movable within safe limits.

With the position of a' fixed, however much a'' may be moved in the joint CG, the lever arms l_1 and l will remain unchanged. Consequenlly, the highest position possible of a'', which makes y_1, the greatest possible, makes T_0, by Eq. 2, the least possible, with a given set of values for the forces h. In fact, the form of Eq. 2 shows, in general, that in order to have T_0 as small as possible, a'' should be as high as possible. In general, also, a' should be as low (or as near to M) as possible in the joint ML; but, since a movement of a' in some cases may increase l and decrease l_1, or *vice versa*, it may be necessary to locate that point in some position higher than its lowest in such cases.

Such, with a given set of values of the pressures h, is the general method of determining the most probable (*i. e.*, least) value of the thrust T_0 by aid of the principle of least resistance.

It has been observed that the pressures h (usually conjugate to the vertical) have possible values lying between certain limits, and, in the general case, they may have varying possible directions.

Eq. 2 shows that, if other things remain the same, T_0 will decrease as Σhl decreases. Consequently, by the principle of least resistance, the pressures, h, should be so taken that their magnitudes and lever arms may be the least possible; or, analytically, Σhl should be the least possible.

The preceding methods and observations are perfectly general, and apply to all cases whatever; but if the characteristics of a given case are simple, their applications become correspondingly easy.

ART. 7.—SPECIAL CONDITIONS. It frequently happens that the entire loading of an arch, if reduced to a uniform mass of the same density as that of the ring stones, may be taken as limited by a plane upper surface, BE, without sensible error. A sloping plane upper surface, like that in Fig. 1, will first be considered. With such a loading the pressures h are usually conjugate to the vertical and parallel to BE, in which case their direction is fixed and cannot change, however much the magnitudes or intensities may vary. Under these circumstances, with a given location of a', the lever arms l are invariable. In seeking the least value of T_0 by Eq. 2, therefore, the forces h are to be taken as the least possible when y_1 and l_1 are fixed.

If the upper surface BE, Fig. 1, or conjugate direction, becomes horizontal, the forces h are horizontal forces, and the lever arms l are simply the vertical distances from the action lines of those forces to the point a'; and as before, in seeking T_0, Σhl is to be made as small as possible by decreasing h only. In this restricted case, if the springing joint LM is horizontal, the lever arms l are absolutely invariable. Consequently, while, as before, a'' is to be taken as high as possible in the joint CG, the point a' is always to be placed as near as possible to M, because l_1 will then have its least value, and y_1 will be independent of the position of a'; the least values of h will then secure the least possible value of T_0.

Whatever may be the inclination of the springing joint LM, and whatever may be the character of the loading, if the forces h are all zero, the value of T_0 becomes:

$$T_0 = \frac{W l_1}{y_1} \qquad (3)$$

As l_1 decreases on the approach of a' to M, and as y_1 increases as a'' departs from G, Eq. 3 shows that for the least value of T_0, in

this case, *the center of resistance at the springing joint must approach the soffit as near as possible, while in the joint CG that center should be as far as possible from the soffit.*

This case would occur if the load were wholly vertical and applied to the ring stones at isolated points.

ART. 8.—DETERMINATION OF THE REACTION R. The preceding methods will give, in all cases, the most probable value for the thrust T_0; but there still remains the force R, or reaction, applied to the springing joint. It is to be found as follows, by the aid of the force polygon:

Fig. 2 represents the arch ring *LCNOGM* of Fig. 1, with the external forces acting on each of the stones of which it is formed The force 1 in Fig. 2 is the resultant of the external forces acting upon the stone *LMa*, Fig. 1; these external forces include h_1, and the weight of the stone itself, as has already been explained. In the same manner the forces 2, 3, etc., Fig. 2, are the resultant external forces acting upon the second, third, etc., stones from *LM* respectively.

The upper part, T_0 4 3 2 1, of Fig. 3, represents these forces laid off in their proper directions, *i. e.*, around the polygon in the same way. The remaining side, R, of the polygon will give the direction and magnitude of the reaction R acting through a'. In the same manner the external forces acting on the stones between *CG* and *ON*, combined with T_0, will give the other reaction R_1, whose point of application, a_1, is not yet known.

The line of resistance $a'abca''$ (a'' is at the intersection of the action line of T_0 and *CG*, Fig. 2, and is also shown in Fig. 1) can now be constructed by the ordinary method. In Fig. 3 P is at the intersection of R and R_1. From P radial lines are drawn to the different angles of the polygon as shown. In Fig. 2 the line of action of R is prolonged until it cuts that of force 1 (also prolonged if necessary). From the intersection of 1 and R the line 9, Fig. 2, is drawn parallel to 9 of Fig. 3 until it cuts the line of action of force 2. From this last intersection the line 10 is drawn parallel to the same figured line in Fig. 3 until it cuts the line of action of force 3. This simple operation is repeated and continued throughout the arch ring until from the intersection of 13 and 7, Fig. 2, a line (R_1) is drawn parallel to R_1 of Fig 3. The intersection of this line with the joint *ON* gives the point of application of the reaction R_1, a point not before known.

ART. 9.—CENTERS OF RESISTANCE AND LINE OF RESISTANCE. The intersection of the various joints (or the joints prolonged) with the lines *R*, 9, 10, 11, etc., Fig. 2 (or those lines prolonged), are the centers of resistance of those joints. Found continuously, they constitute the line of resistance for the arch ring. In order that the stability of position may be secured for each joint, its center of resistance must be found within a certain distance of its center of figure; this distance is frequently indicated by *qt*, which has already been used.

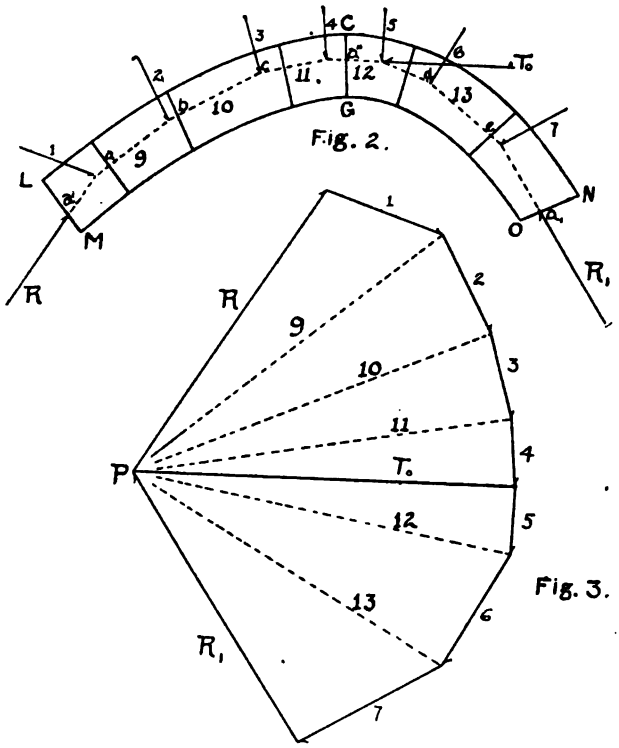


Fig. 2.

Fig. 3.

With the first trial value of T_0, it will frequently, and perhaps always, be found that the consequent construction will give some centers of resistance lying further from the center of figure than *qt*. It will then be desirable so to change T_0 that the resulting line of resistance will, if possible, lie within the proper limits.

A consideration of Fig. 3, in connection with Fig. 2, will show, in a general way, in what manner a change in T_0 or the values of the pressures *h* will influence the location of the centers of resistance.

If the pressures h remain the same while T_0 becomes smaller the dotted lines in Fig. 3 will become steeper, consquently all points in the line of resistance will rise relatively to the end points a' and a_1. On the contrary, if, while the other circumstances remain the same T_0 becomes larger all points will fall relatively to the points a' and a_1. If the point a'' in CG remains fixed while the same changes take place a decrease in the value of T_0 will cause all the other centers of resistance to fall, while an increase will cause them to rise.

If the pressures h are conjugate to the vertical, *i. e.*, parallel to BE in Fig. 1, it is not easy to predict, without reference to a particular case, what effect a uniform variation of those pressures will always produce, and much less so when they are not conjugate. It may be stated as a general principle, however, that any variation whatever, either in the values of T_0 or h, which makes the lines radiating from P, Fig. 3, more inclined to a horizontal line will make the line of resistance more concave downward (or convex upward), while any variations in those quantitles which cause the lines radiating from P to become less inclined will make the line of resistance less concave downward (or convex upward).

The preceding simple observations taken in connection with the circumstances of any particular case will enable the centers of resistance to be located within safe limits, if possible after one or two trials; and in the event of its not being possible the necessity of increasing the depth of the arch ring will be shown.

It is proper to observe that the polygon R, 9, 10, 11, 12, etc., is not necessarily the polygon, or line, of resistance, though it is in most cases. That line is the polygon (or line) of pressures, and it is sometimes neccssary to produce the sides of the polygon of pressures to the corresponding joints (as has before been observed) in order to find the centers of resistance.

ART. 10.—NECESSITY FOR LARGE SCALE DRAWINGS. In applying equations 1, 2 and 3 it is supposed that the lever arms l, l_1 and y_1 are measured from a large-scale drawing; it is also supposed that the magnitude and position of the forces 1, 2, 3, 4, 5, etc., are found by construction in the same drawing.

ART. 11.—METHOD OF PASSING POLYGONAL FRAME THROUGH THREE ASSUMED POINTS. The second method of determining the line of resistance of an arch involves the problem of passing the line of resistance through three assumed points in an arch ring.

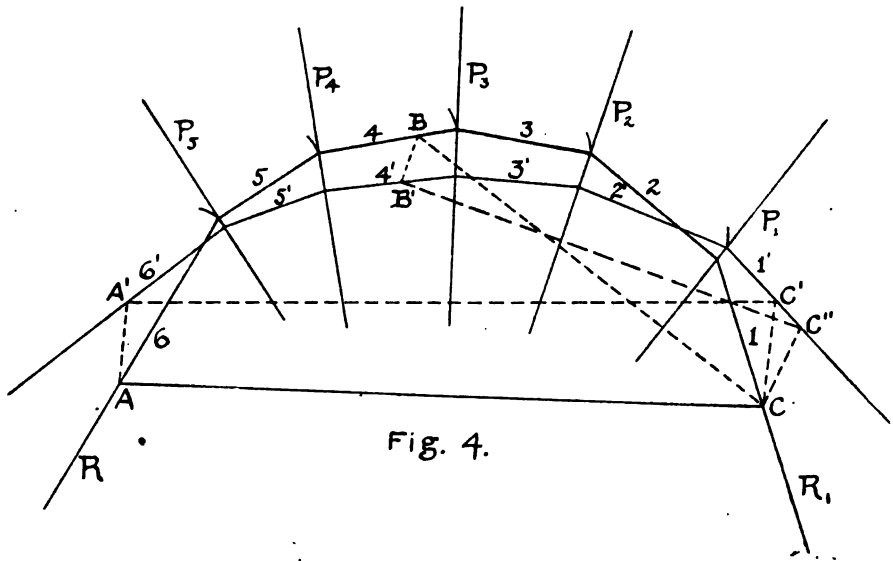
No reference is made to the principle of least resistance. The resultant external force for each ring stone, including its own weight, is found and used precisely as before. It is most convenient, however, to consider the entire arch ring rather than a portion of it in connection with the thrust T_0 at the crown. It will first be necessary to treat the preliminary problem.

ART. 12.—TO PASS THE POLYGONAL FRAME THROUGH ANY THREE POINTS. Let the system of external (given) forces or loads P_1, P_2, P_3, P_4 and P_5 in Fig. 4, together with the reactions or supporting forces R and R_1 (to be found), constitute a system in equilibrium. It is then required to find a polygonal frame which shall pass through the three points A, B and C. In Fig. 5 the force polygon P_1, P_2, P_3, P_4, P_5 and ab is laid down in the usual manner to any convenient scale. The pole p' is taken at any point, and the radiating lines 1′, 2′, 3′ ... 6′ are then drawn: From some point in the line of action of a force as P_3, Fig. 4, near the middle of the system the polygonal frame 1′, 2′, 3′ ... 6′ is drawn with sides parallel to the lines radiating from p' in Fig. 5. It is best to start this trial frame from a point near the middle of the load system and work each way from it, in order to reduce errors of construction which would accumulate to a greater amount if the frame were begun at one end and constructed continuously to the other.

From A and C are then drawn the lines CC' and AA' in Fig. 4 parallel to ab in Fig. 5 to their intersections with the frame at A' and C'. The line $A'C'$ will then be the closing line of the frame, and if $p'H$ be drawn parallel to it in Fig. 5 to bH will be a component parallel to ba of every reaction R_1, while aH will be a similar component of every reaction R. Inasmuch as ba is the resultant of the system P_1, P_2, ... P_5, the sum of the two components parallel to ba of the two reactions R and R_1 must always be equal to that resultant, whatever frame be constructed.

The closing line of every frame passing through A and C must be AC. Hence in Fig. 5 from H draw the line Hp parallel to AC in Fig. 4. If radiating lines be drawn from any point on the line Hp indefinitely extended any frame with sides parallel to those radiating lines will pass through A and C. It is necessary next to find the pole p of that particular frame which passes through B, Fig. 4.

The forces or loads P_1 P_2 and P_3 lie between C and B, and their


P4
P3
P2
P5
P1
B
B'
A'
C'
C''
A
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R
R1
1
1'
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4
4'
5
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6
6'

Fig. 4.

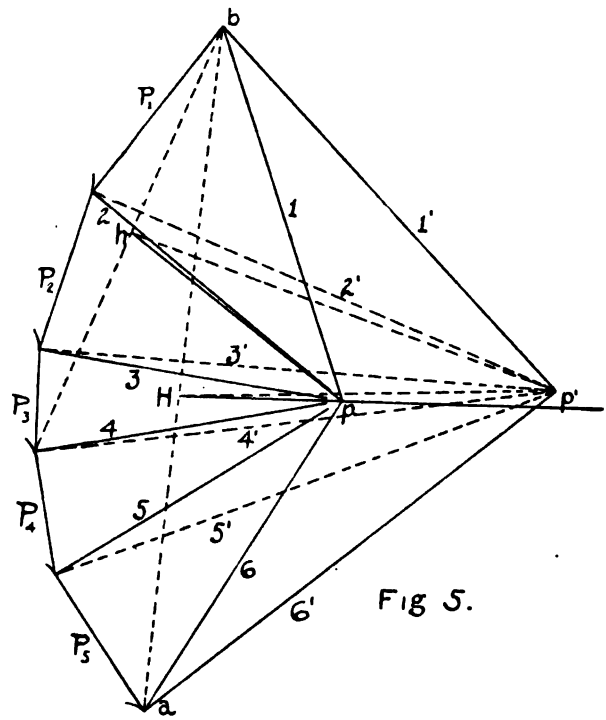

b
P1
P2
P3
P4
P5
H
H'
p
p'
a
1
1'
2
2'
3
3'
4
4'
5
5'
6
6'

Fig 5.

resultant is *bc* of Fig. 5. Hence in Fig. 4 draw the lines BB' and and CC' parallel to *bc* of Fig. 5. B' C' is the closing line of the trial frame for P_1 P_2 and P_3. Hence in Fig. 5 draw the line p' h parallel to B' C', and then from h so determined draw hp parallel to the real closing line BC until it intersects Hp in p, hp indefinitely produced is the locus of all poles of frames for P_1 P_2 and P_3, which will pass through B and C. Hence p, at the intersection of Hp and hp, is the pole for a frame (or line of resistance) which will pass through the three points A, B and C. The radiating lines 1, 2, 3, 4, 5 and 6 drawn from p will determine the sides of the desired frame 1, 2, 3, 4, 5 and 6 in Fig. 5. The sides of the polygonal frame determine, by their intersections with the joints of an arch, the "line of resistance" of the arch ring."

ART. 13.—GENERAL METHOD OF PROCEDURE. After a line of resistance has been constructed by the method of the preceding Art. to pass through the three assumed points, usually one at each springing joint or skew back and one at the crown, it may be found to lie outside of the desired limits at one or more joints. It will then be necessary to modify the variable elements of the problem, as was done in the preceding method, so as to determine a line of resistance, if possible, which will lie within the desired limits. If this latter result cannot be reached then it will be necessary to increase the thickness of the arch ring until a line of resistance can be constructed within the prescribed limits.

In selecting the three assumed points through which the trial polygonal frame must pass, the judgment must be exercised both as to the manner of loading and as to the variable features of that frame set forth under the discussion of the preceding method.

ART. 14.—SAFE LIMITS FOR THE LINE OF RESISTANCE. There are thus found complete methods by which it can be determined whether or not a line of resistance can be constructed within the safe limits of any given arch ring, or by which an arch can be designed of such dimensions that a line of resistance may be found within safe limits. It then becomes a matter of importance to determine what those "safe limits" are. The matter can only be exactly settled by experience, but there are certain considerations of great weight which should be borne in mind in connection with the empirical aspect of the question.

Some authorities, as Rankine, consider the "safe limit" to be the middle third of the arch ring, in which case $q = \frac{1}{6}$; others

make $q = \frac{1}{4}$, or, the "safe limit," the middle half of the arch ring.

In all cases it is virtually assumed that the pressure exerted on any joint is one of uniformly varying intensity. The probability of the exact truth of this assumption is very slight indeed, if any exists at all, but it is the best hypothesis that can be advanced.

When q is taken as $\frac{1}{6}$ it is made certain that no tension can exist at any part of the joint. Fig. 6 represents this case.

All lines parallel to *Aa* represent *intensities* of stress; that line itself standing for the greatest intensity existing in the joint, while $Ab = t$ is the joint, or rather a trace of its plane. The intensity at *b* is zero. The stress existing in *Ab* is simply a system of parallel forces whose center is at *R*, $\frac{1}{3}$ of *Ab* from *A*, or $\frac{1}{6}$ *t* from the middle point of *Ab*. If the center of stress *R* never approaches nearer to *A*, pressure only can exist in the joint and it (the joint) will never tend to open. Thus, no portion of the joint will ever be subjected to tension, and since it is not safe to rely upon an ordinary masonry joint to resist tension it is thought that q should have the limiting value of $\frac{1}{6}$.

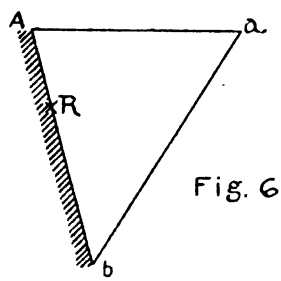


Fig. 6.

It does not follow, however, that the joint will necessarily begin to open if *R* approaches nearer to *A* than $\frac{1}{3}$ *t*, or that the stability of the arch is necessarily endangered if the joint does begin to open.

In Fig. 7 the greatest intensity of stress is *Aa*. At *b* the intensity is zero, while no stress at all acts on *Bb*. *R* being the center of stress the distance *AR* is one-third of *Ab*. If the intensity *Aa* does not exceed the ultimate resistance to compression of the material there can be no opening at *B*, except that due to the elasticity of the material between *b* and *A*, and that is scarcely sufficient to bring the case within the meaning of an "open joint." If the material at *A* is crushed, the joint truly begins to open; but even then the stability is not necessarily destroyed. In that case

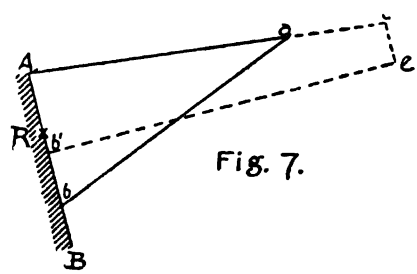


Fig. 7.

the area representing the stress acting at the joint is *Adeb'*, *Ad* be-the ultimate resistance to compression. The intensity is uniform in the vicinity of *A*, over an area indicated by *de*, and the center of pressure, or resistance, is nearer to *A* than *R*. Eventually, when the area of uniform intensity equal to the ultimate resistance to compression indicated by *de*, becomes too great, the whole ring stone will crush and the arch will fall, but not before. It is thus seen that the value of *q* may considerably exceed ⅙, while the stability of the arch remains secured, even on the safe and proper supposition that the joint cannot resist tension.

If the joint were capable of exerting tensile stress its condition would be given by Fig. 8. The triangle *bBc* may represent tension while *Aac* represents compression. Since, however, it is not prudent to rely upon the tensile resistance of a mortar joint let the Figs. 6 and 7 again be considered.

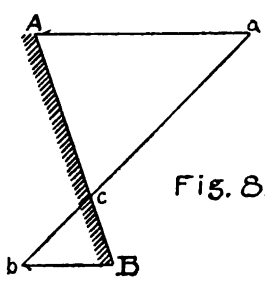


Fig. 8.

ART. 15.—WORKING STRESSES. It certainly is dangerous to allow the greatest intensity of stress *Aa* to approach the ultimate resistance to compression of the material, and since the portion *bB* of the joint in Fig. 7 is useless the best method of procedure is to take $q = \frac{1}{6}$ and give the greatest intensity of stress, *Aa*, a reasonable value. According to Rankine (Civil Engineering), in many arches which are considered first-class specimens of their kind the depth of key-stone is such that the ultimate resistance to crushing is from 3 to 70 times the greatest intensity of stress acting in it; while he remarks that the first value is too small and the latter too large. If the depth of arch ring is so designed that the greatest intensity of pressure, acting on any joint, under the heaviest loading is from 1-20 to 1-30 the ultimate resistance to crushing of the stone of which the arch ring is built ample security will be provided. While it is difficult, if not impossible, with the experimental data at hand, to state, with even approximate certainty, the relation existing between the ultimate resistance of the blocks of stone used in a given piece of masonry and that of the completed masonry, it is probably reasonable to take the safe working resistance in the arch ring at ⅛ to $\frac{1}{12}$ the ultimate resistance of the completed masonry, when well laid in good Portland cement mortar. The latter is

known fairly well for concrete and brick, but scarcely at all for other classes of masonry.

If the ultimate resistance per unit of area of cubes of the stone be represented by C, while the greatest intensity of working pressure in the arch ring is C', the following values will be used hereafter:

$$q = \tfrac{1}{6}, \text{ and } C' = \frac{C}{20} \text{ to } \frac{C}{30}. \qquad (4)$$

Since C' can exist at but one point in the section, the value of C may be taken as that belonging to large cubes, which is considerably larger than that belonging to small cubes.

ART. 16.—LIMITING VALUES OF CONJUGATE PRESSURES. In fixing the limits of the pressures h, no little difficulty arises in many cases. If the spandril filling is of dry or ideal earth, the limits are well defined; the lower is the conjugate pressure of earth loaded with its own weight, while the upper is simply the abutting power of the same earth. Such earth, however, is seldom or never found. Damp earth solidly packed, whose tenacity and compressive resistance are considerable, is the material usually found over the ring stones of an arch whose filling is not masonry. Such earth is capable of exerting a pressure against the ring stones with an intensity varying from 0 to some value higher than the abutting power of the same earth when dry and granular. It is usually impossible to determine the upper limit of this intensity by experiment, consequently the value to be taken must be a result of the judgment acting upon all the circumstances of the particular case. It should be a matter of care not to take too high a value, for such an error would involve a mistake on the side of danger in the question of stability; the value should be too small rather than too large.

ART. 17.—INFLUENCE OF SPANDRIL FILLING. If the spandril filling is of masonry, so far as the stability of the arch ring is concerned, the intensity of the pressure h may vary from zero to the working resistance to compression of the material of the spandril, if it is less than that of the arch ring. It is implied, however, that the values of h will not be of such magnitude as to give T_0 a value sufficiently large to cause the center of resistance of the lowest joint in the abutment to move outside the safe limits. To illustrate this matter, let Fig. 9 represent half of an arch with its abutment. T_0 and the pressure acting against DE are supposed to be horizontal in direction, but they are opposite to each other.

Let their difference be represented by H. W is the weight of the mass, $BCED$, acting through G' (in the line of action of T_0) and the centroid G. The resultant force, therefore, acting on the half arch and abutment, will be R, and its line of action cuts the lowest joint, DB at A, the center of resistance. The pressures h must not be large enough so to increase the value of T_0, and hence H, that the point A will be found at a distance greater than qt from the middle point of DB. This implicit condition is always to be borne in mind.

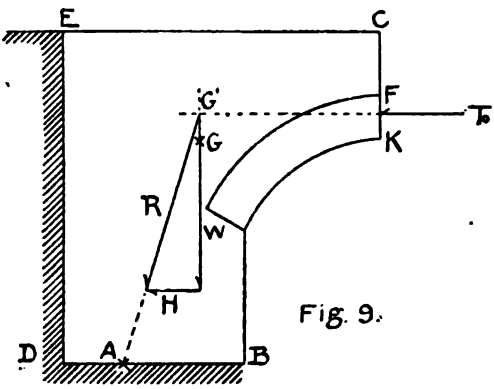


Fig. 9.

ART. 18.—APPROXIMATE DEPTH OF KEY-STONE. In designing an arch much time and trouble may be saved by an approximate rule for fixing a trial depth of key-stone, and such a rule may easily be established.

Let the heaviest moving load (covering the whole arch) and all the fixed load, including the weight of the ring stones, be reduced to a mass of the same density as that of the ring stones or voussoirs, in Fig. 9, and let the horizontal line EC be supposed to limit the upper surface of such a mass. At the crown, F, the arch will be normally pressed by a load whose intensity may be represented by $KC = d$. The radius of the line of resistance (or linear arch) at the crown may not be very different from that of the intrados at the same point; hence they will be taken as equal and denoted by r, while w will represent the weight per cubic unit of the arch ring.

If then k is the depth of the key-stone, there will result.*

$$T_0 = \frac{kC'}{2} = wdr \tag{5}$$

$$\therefore k = \frac{2w}{C'} dr. \tag{6}$$

This, of course, is only an approximate formula and is limited

*The condition of stress exhibited by Fig. 6 is supposed to exist at the crown. Hence q will be equal to $\frac{1}{8}$.

by all the conditions assumed, but it furnishes an excellent first-trial value for the depth of key-stone.

If, for good limestone, $C' = 70{,}000$ pounds (per square foot), and $w = 165$ pounds, there will result:

$$k = 0.005\, dr \text{ (nearly)} \qquad (7)$$

in which d must be taken in feet. According as r is given in feet or inches, k will be found in feet or inches also. Ordinarily r is given in feet.

In any case of importance the value of C (hence also of C') should be determined by experiment with the stone to be used.

As with truss bridges so with arches, the moving load, per unit of span, may be decreased as the span increases. For this reason the quantity d has been assumed by some to vary inversely as the square root of the radius at the crown. Under such an assumption, if the radius at the crown is supposed to be proportional to the span and if c is a constant, Eq. 6 or 7 will take the form:

$$k = \frac{c}{\sqrt{r}} r = c\sqrt{r} = \sqrt{c^2 r}. \qquad (8)$$

Rankine, in his "Civil Engineering," gives $c^2 = 0.12$ for a single arch and 0.17 for one in a series.

This assumption, however, does not seem to be warranted by the circumstances of actual loading. The moving load for arches certainly cannot be supposed to vary inversely as some function of the span any more rapidly than does that for truss bridges. For the latter class the variation may very well be shown by taking a moving load per foot of span of 6,000 pounds for a 25-foot, and 3,500 pounds for a 500-foot span. If the law were expressed by the reciprocal of the square root of the span, the loads per foot would be 4,500 pounds and 1,330 pounds (nearly). Hence the moving load does not decrease nearly as rapidly as the law requires. Again, in general, the depth of fixed load at crown will increase as the span increases; this will tend to balance the decrease in the moving load.

Eq. 8, therefore, cannot express the law of variation of the thickness k with any very close degree of approximation. It should be observed, however, that, as Rankine shows it does give very closely the actual depths of the key-stone of many arches that have stood well for many years. Such evidence, however, is not conclusive

unless it can be shown that there is neither excess nor deficiency of material in the arches taken as examples.

Equation 6 shows that the depth of the key-stone will vary approximately as the product of the total load at the crown by the radius at the same point and inversely as the permissible working pressure for the stone or masonry used. If the total load and working pressure are constant, the depth of key-stone will vary approximately as the radius at the crown. In a great many existing arches k ranges from $\frac{r}{10}$ (for radius of 20 feet) to $\frac{r}{30}$ (for radius of 160 feet).

ART. 19.—EMPIRICAL FORMULÆ FOR DEPTHS OF KEY-STONE. The following empirical formulæ for arches have been proposed by different authorities and will serve at least to fix trial depths of key-stones or for approximate estimates:

Let v = rise or vers-sine of arch in feet.
" s = span of arch in feet.
" k = depth or thickness in feet of the arch ring at crown.
" R = radius of the intrados in feet, at crown.
" r = radius in feet of the circle which will touch the intrados at crown and the two springing joints, the latter being at the same elevation.
Let h = height or depth of earth loading at the crown, in feet.
" H = height of abutment, *i. e.*, from springing line to top of foundation, in feet.
" E = thickness of abutment in feet.

Then there has been proposed:

$$E = 1 + 0.04\,(5s + 4H). \tag{9}$$

Perronet's rule is as follows:

$$k = 1 + 0.035s. \tag{10}$$

Dejardin has proposed the following rules:

Semi-circular arch; $e = 1 + 0.1\,R.$ (11)

Segmented Arches:

$$\frac{v}{s} = \tfrac{1}{6};\ k = 1 + 0.05\,R; \tag{12}$$

$$\frac{v}{s} = \tfrac{1}{8};\ k = 1 + 0.035\,R; \tag{13}$$

$$\frac{v}{s} = \tfrac{1}{10};\ k = 1 + 0.02\,R. \tag{14}$$

Elliptical, false elliptical or basket-handle arches:

$$\frac{v}{s} = \tfrac{1}{8}\,;\; k = 1 + 0.07R. \qquad (15)$$

If it is necessary to take into account the height of the earth loading at the crown;

$$k = 1 + 0.035s + 0.02h. \qquad (16)$$

It has been found that if the vertical projection of each and every joint is equal to the depth at the crown (*i. e.*, equal to *e*) the arch will usually be stable. This rule is to be applied only to those joints between the crown and that one whose inclination to a vertical plane through the axis of the arch is 60 degrees.

Trautwine's rule is:—

For first class cut stone:

$$k = \frac{\sqrt{r + \frac{1}{2}s}}{4} + 0.2. \qquad (17)$$

For second class work:

$$k = \frac{9}{8}\left(\frac{\sqrt{r + \frac{1}{2}s}}{4} + 0.2\right). \qquad (18)$$

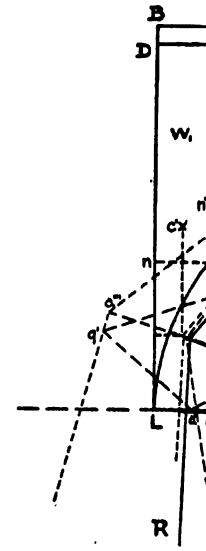
For brick or fine rubble:

$$k = \frac{4}{3}\left(\frac{\sqrt{r + \frac{1}{2}s}}{4} + 0.2\right). \qquad (61)$$

ART. 20.—FRICTIONAL STABILITY. The simple matter of frictional stability yet remains to be noticed. No sliding of blocks upon each other can take place if the greatest obliquity of resultant pressure at any joint does not exceed the angle of repose. The obliquity of resultant pressure is at once obtainable after the true force polygon is known. Hence the means by which the stability of position is secured will also give all the information desired in reference to the stability of friction.

The angle of repose for the sliding of masonry on masonry is not a very well defined quantity, but it is usually taken so that its tangent (the coefficient of friction) varies approximately from 0.6 to 0.75.

ART. 21.—DESIGN OF ARCH RING FOR UNIFORM MOVING LOAD OVER ENTIRE SPAN. The application of the preceding general principles will be illustrated in this and the succeeding Art. by first taking the moving load uniformly over the entire span and


B
D
W
L
R

then over two-thirds of the span. In general it will be necessary to consider, as one condition, the moving load over the entire span. The other condition may be either the moving load over one-half the span, or somewhat more than one-half, as five-eighths or two-thirds. In the present instance, in the next Art., the moving load will be taken over two-thirds of the span.

The elliptic arch shown in Fig. 10 will be considered covered by a uniform moving load. The arch ring *MLCG* is of the uniform thickness 5.4 feet. The principal dimensions are the following:

Half Span, $MN = 65.00$ feet.
The Rise, $NG = 32.50$ feet.
Thickness, $GC = LM = 5.40$ feet.
Depth of Loading, $AC = BD = 2.17$ feet.

The complete arch is semi-elliptic. Hence, *MN* and *NG* are semi-transverse and semi-conjugate axes, respectively. The radius of curvature at *G* will, then, be $(65)^2 \div 32.5 = 4 \times 32.5 = 130.00$ feet.

For convenience of calculation the weight of the arch ring and its loading (reduced to the same density) will be taken at 150 pounds per cubic foot. It will be assumed, for a purpose of comparison hereafter, that the upper surface of the total load (moving and fixed), reduced to the same density with the ring stones, is the plane whose trace is *BA*. The figure *ABLMGA* will then represent, for the half arch, a mass of material of the uniform density of 150 pounds per cubic foot. The arch ring is divided into eight parts by the joints shown at *b*, *d*, *t*, *f*, *l*, *o* and *p*. From the upper extremities of those joints vertical lines are drawn, a_1a, c_1c, etc., to *BA*, in such a manner that Be_1 is divided into three equal parts and e_1A into five such parts.

$$Ba_1 = a_1c_1 = \text{etc.} = 5.42 \text{ feet.}$$
$$e_1f_1 = f_1l_1 = \text{etc.} = 10.83 \text{ "}$$

The centers of gravity of the various six-sided figures comprised between the different pairs of vertical lines and corresponding joints, as shown at c', c'', c''', etc., were found by trial with a knife edge. The arch and loading were laid down, to a large scale, on heavy paper; the different portions, as $a_1c_1cdbaa_1$, were then cut out and carefully balanced on the knife edge. The center of gravity of the entire half arch and load was, in the same manner, found to be at the point *g*. The areas of these portions were easily

and accurately found from the same large scale drawing. Since the curve MG is the quadrant of an ellipse the total area of the figure is

$$BA \times AG + LM \times GN + MN \times GN\left(1 - \frac{\pi}{4}\right) = 1163 \text{ square feet.}$$

These different areas multiplied by 150 will give the weights of the same portions. The various weights found in this manner are given below and are represented in the figure by the full portions of the vertical lines drawn through the various centers c', c'', c''', etc.:

$W_1 = 39.300$	pounds.	$W_5 = 21,045$	pounds.
$W_2 = 24.370$	"	$W_6 = 16,605$	"
$W_3 = 18,705$	"	$W_7 = 13.755$	"
$W_4 = 27,765$	"	$W_8 = 12,900$	"

Total weight for half arch, $W = 174,400$ pounds.

The conjugate forces h, each acting against a portion of the arch ring, are taken horizontal. The spandril filling will be assumed to be earth in such quantity that it and its load alone will make a mass, of the outline described, with the average weight of 150 pounds per cubic foot. The conjugate (horizontal) pressure at any point will, therefore, be found either by treating the spandril filling as earth weighing 150 pounds per cubic foot, or as weighing 100 pounds per cubic foot, but having a depth once and one-half as great as shown by the diagram, Fig. 10. The first of the two methods will be employed. The intensity of each horizontal force will be assumed uniform; consequently its center will be at the center of its surface of action; no sensible error is committed by this assumption. Loose earth would be able to exert a pressure against the arch ring equal to its abutting power. The same earth packed hard, with the aid of the little dampness which it ordinarily absorbs, will be capable of exerting a much greater pressure. The abutting power, however, will be taken as the upper limit and, although the lower limit may be zero in such a case, in the present instance that limit will be taken as the pressure of unloaded earth. For the reasons stated, the earth will be treated as if it weighed 150 pounds per cubic foot, and its angle of repose φ will be taken at 30°. The horizontal force h_1 will act on nL, h_2 on $n'a$, h_3 as $n''c$, etc.

The formulæ for the abutting intensity and for the unloaded

intensity of a mass of loose earth with horizontal upper surface and at the depth x are:

$$\left.\begin{aligned} p &= wx\frac{1+\sin\varphi}{1-\sin\varphi}. \\ p' &= wx\frac{1-\sin\varphi}{1+\sin\varphi}. \end{aligned}\right\} \qquad (20)$$

Inasmuch as the conjugate pressure against the two portions of the arch ring W_7 and W_8 at and near the crown are small they will be omitted. There will then be six conjugate pressures $h_1 \ldots h_6$ to be found. Remembering that a single foot in length (parallel to the axis) of arch is being considered, the areas on which the intensities p or p' act will be the vertical strips nL, $n'a$, $n''c$, etc., and the depth x will be the distances of the centres of those strips below BA, Fig. 10.

The following tabular statement exhibits all the elements of these conjugate pressures and the pressures themselves.

Feet.	*Pounds.*	*Sq. Feet.*	*Pounds.*
$x_1 = 32.5$;	$\left\{\begin{matrix} p = 14\,625 \\ p' = 1{,}625 \end{matrix}\right\}$; $A_1 = 15.5$;	$\left\{\begin{matrix} pA_1 = 226{,}700. \\ p'A_1 = 25{,}200. \end{matrix}\right.$
$x_2 = 22$;	$\left\{\begin{matrix} p = 9{,}900 \\ p' = 1{,}100 \end{matrix}\right\}$; $A_2 = 6$;	$\left\{\begin{matrix} pA_2 = 59{,}400. \\ p'A_2 = 6{,}600. \end{matrix}\right.$
$x_3 = 17$;	$\left\{\begin{matrix} p = 7{,}650 \\ p' = 850 \end{matrix}\right\}$; $A_3 = 4.5$;	$\left\{\begin{matrix} pA_3 = 34{,}425. \\ p'A_3 = 3{,}825. \end{matrix}\right.$
$x_4 = 12.4$;	$\left\{\begin{matrix} p = 5{,}580 \\ p' = 620 \end{matrix}\right\}$; $A_4 = 5.5$;	$\left\{\begin{matrix} pA_4 = 30{,}690. \\ p'A_4 = 3{,}410. \end{matrix}\right.$
$x_5 = 8$;	$\left\{\begin{matrix} p = 3{,}600 \\ p' = 400 \end{matrix}\right\}$; $A_5 = 3.7$;	$\left\{\begin{matrix} pA_5 = 13{,}320. \\ p'A_5 = 1{,}480. \end{matrix}\right.$
$x_6 = 5$;	$\left\{\begin{matrix} p = 2{,}250 \\ p' = 250 \end{matrix}\right\}$; $A_6 = 2.8$;	$\left\{\begin{matrix} pA_6 = 6{,}300. \\ p'A_6 = 700. \end{matrix}\right.$

The extreme right-hand column (products of the type pA) contain the limiting values of the conjugate pressures $h_1 \ldots h_6$.

Although the graphical method of determining the line of resistance is finally to be employed, it is convenient at this point to illustrate that method under which the thrust, T_0, at the crown is found so as to satisfy the principle of least resistance set forth in Art. 6.

The vertical distances of the centres of the surfaces Ln, an', cn'', etc., above the horizontal joint LM, measured from the large scale drawing, are as follows, l_1' belonging to Ln, l_2 to an', etc.:

$l_1' = 7.7$ feet. $\quad l_4 = 27.8$ feet.
$l_2 = 18.2$ " $\quad l_5 = 32.2$ "
$l_3 = 23.2$ " $\quad l_6 = 35.2$ "

In accordance with the principles which have been already stated, the centre of resistance, a', of the joint LM is taken one-third of LM from M; also a'' is one-third of CG from C. Consequently the value of y_1, or the height of a'' above a', is 36.1 feet. T_0 is taken to be horizontal.

Taking the sum of the products $h_1 l_1'$, $h_2 l_2$, etc., there will result the numerical value of Σhl. The horizontal distance of the centre of gravity g from a' is $l_1 = 20.8$ feet; this is the l_1 of the product Wl_1 in Eq. 2. Hence $Wl_1 = 3{,}627{,}520$. If there be taken mean values of the conjugate pressures "pA" as above determined, there will result:

$$\left.\begin{array}{ll} h_1 = 125{,}000 \text{ lbs.} & h_4 = 17{,}000 \text{ lbs.} \\ h_2 = 33{,}000 \text{ "} & h_5 = 7{,}200 \text{ "} \\ h_3 = 19{,}000 \text{ "} & h_6 = 3.500 \text{ "} \end{array}\right\} \qquad (21)$$

If the products of these values by their lever arms, together with the product Wl_1, be placed in Eq. (2) of Art. 6, the thrust T_0 will have the value:

$$T_0 = \frac{6{,}459{,}060 \text{ ft. lbs.}}{36.1} = 178{,}900 \text{ lbs.}$$

If the resultant of each of the weights W_1, W_2,...and the conjugate pressure h_1, h_2,...be found, and then if the line of resistance be constructed with the thrust T_0 as determined above, it would probably be found that that line of resistance lies within the middle third of the arch ring; and, hence, that the arch is stable. Otherwise it would be necessary so to vary some or all of the pressures h (and T_0 correspondingly) as to bring the line of resistance within the desired limits, if possible; or, finally, to increase the depth of the arch ring if it should prove necessary.

In proceeding with the graphical method the horizontal or conjugate pressure given in Equation (21) will be employed. Each of the horizontal pressures $h_1 \ldots h_6$ is combined with the corresponding weight $W_1, \ldots W_6$ so as to obtain the resultant force on each portion of the arch ring, all as shown in the left half of Fig. 10. In that figure each such resultant force (except 2') is shown in its true magnitude and position, and they are indicated by the figures 1, 2, 3, 4, 5, 6, 7 and 8. The forces 1 and 2 are modifications of 1' and 2' in Fig. 11, as will immediately be explained. After the

resultants 1′, 2′, 3, 4, ... 8, are thus determined the force polygon is laid down as shown in Fig. 11, with the arbitrary pole distance *ac* horizontal, since it represents a trial value of the horizontal thrust, at the crown of the arch. The radial broken lines drawn from *a* will then be parallel to the sides of a trial polygonal frame to be drawn in the arch ring. It will be assumed that this trial frame must pass through a point in the joint *f* two feet from its upper extremity, it being the ultimate purpose of the construction to find a line of resistance, if possible, which shall lie in the middle third of the ring. A line is then drawn through the described point in the joint *f*, Fig. 10, parallel to *ag*, Fig. 11, until it intersects the resultant forces 4 and 5 as laid down in the arch ring. From those points of intersection lines are then drawn parallel to *ak* and *am* of Fig. 11 until the lines of action of the forces 3 and 6 are intersected. These operations are repeated until the entire frame $q'a'''a''q$, shown by broken lines, is constructed for the half arch. The points q' and q are located as follows: It is desired to determine a frame which shall pass through a'' in the crown joint, the point in the joint *f* already described and a' in the springing joint; the point a'' being one-third of the depth of the joint from the top *C* of the ring, and a' one-third the depth of the ring from the soffit at *M*. Hence $a''q$ and $a'q'$, Fig. 10, are drawn parallel to *dc* in Fig. 11 until they intersect the frame in the points q and q', thus establishing the latter. The reasons for this construction and those which immediately follow will be found in Art. 12.

In Fig. 11 the line *ae* is next drawn parallel to qq' in Fig. 10. The line *be* in Fig. 11 is then drawn parallel to $a''a'$ in Fig. 10, thus locating the desired pole *b* for the force polygon. The full and broken radiating lines are then drawn from *b*, Fig. 11, to the extremities of the forces 1′, 2′, 3, 4, 5, 6, 7, 8. In Fig. 10 the polygonal frame shown by broken lines and running from a'' through the original point in the joint *f* to a' is constructed in the usual manner, with sides parallel to the radiating lines from *b* in Fig. 11. The line of resistance of the half arch ring is the line passing through the intersections of the several sides of the frame with the corresponding joints.

This line of resistance lies within the middle third of the arch ring and as the two halves of the arch are symmetrically loaded the entire arch is satisfactorily stable. The reaction R', however, has a somewhat unreasonable direction in consequence of the

horizontal pressures h_1 and h_2 being larger than necessary. There will be taken, therefore, $h_1 = 100{,}000$ pounds and $h_2 = 25{,}000$ pounds. The forces 1 and 2 will then be found as shown by the full lines in Fig. 11, with the corresponding full radiating lines from *b*. Two sides only of the frame will be changed, *i. e.*, that one which cuts *LM*, Fig. 10, and the one immediately above it. These modifications of the frame are shown by broken lines in that figure. Obviously the center of resistance in the joint *LM* will now lie much nearer *L* than before.

The line of resistance thus found is seen to lie practically along the upper limit of the middle third of the ring. Let, therefore, a line of resistance be constrcted by starting at the middle point of the crown joint the same polygonal frameas that first determined (by the full line force polygon *cbn* 1, 2, ···, 8 of Fig. 11). The full line frame, with the reaction *R*, shows the resulting line of resistance to be located near the center line of the arch. The stability of the arch is, therefore, completely established.

The crown thrust, given by *bc*, Fig. 11, scales 179,000 pounds, while the reaction *R* (*bn*) is 176,000 pounds. No resultant force on a joint exceeds 180,000 pounds, which is exerted on joint *o*. Hence the maximum intensity of pressure in the ring is $\frac{180{,}000}{5.4}$ = 33,330 pounds per square foot, which is well within the limits of safety. The greatest obliquity of pressure on any joint is shown by the diagram not to exceed about ten degrees; hence stability of friction is amply secured.

ART. 22.—DESIGN OF ARCH RING FOR UNIFORM MOVING LOAD OVER TWO-THIRDS OF SPAN. The design to be treated in this Art. is identical with that considered in Art. 21, except that the moving load will be taken over two-thirds of the span instead of the entire span. Fig. 12 represents the arch which is identical with Fig. 10, except as to the lines over the arch ring pertaining to the loading. The length of uniform moving load is shown by *AL*, and it will be observed that the division *BD*, Fig. 12, corresponds to the two divisions $a_1c_1e_1$ of Fig. 10. In this case the weight of the masonry will be taken at 160 pounds per cubic foot. The spandril filling between $A'Q'$ and the arch ring, will be considered earth weighing 100 pounds per cubic foot. The rectangles *AL* by AA' and *LQ* by QQ' represent the moving load, and the fixed load above the spandril earth filling reduced to a uniform density of 160

pounds per cubic foot. The curved line $tt't_1$ represents the upper surface of the spandril earth filling reduced to the same density of the arch ring, $tt'' = t't''' =$ etc. $= AA'$. The curved broken lines in the right hand spandril have a corresponding signification. The divisions bounded by these broken curved lines, the vertical sides and the line of the soffit were cut out of stiff manilla paper and then balanced on a knife edge so as to determine the centers of gravity W_1, W_2, W_3, etc. The weights of these various portions are shown by the full portions of the vertical lines drawn through the centers of gravity.

The main data of the problem are as follows:

Half span $= TC_1 = 65$ ft. Rise $CC_1 = 32.5$ ft.

Thickness or depth of arch ring $= CK' = 5.4$ ft.

$AB = PQ = 5.4$ ft. $BD = \cdots = FH = LM = \cdots = OP = 10.83$ ft.

$HK = KL = 21.67$ ft.

$AA' = 2\,QQ' = 3$ ft. $QQ' = 1.5$ ft.

$St = \frac{5}{8}\,SA'$. $at' = \frac{5}{8}\,aB'$, etc.

The weights of the various portions of the arch ring, spandril and loading, determined in the manner already described, are as follows:

$W_1 = 31{,}385$ lbs.	$W_7' = 30{,}100$ lbs.
$W_2 = 36{,}897$ "	$W_8 = 34{,}300$ "
$W_3 = 27{,}479$ "	$W_9 = 24{,}900$ "
$W = 21{,}914$ "	$W_{10} = 19{,}300$ "
$W_5 = 18{,}298$ "	$W_{11} = 15{,}700$ "
$W_6 = 33{,}270$ "	$W_{12} = 33{,}300$ "

The conjugate (horizontal) pressures against the vertical projections of portions of the ring stones are due to the earth spandril filling and the load above it. The amount or depth of earth corresponding to the latter load is $\frac{160}{100} = \frac{8}{5}$ of AA' for the left half of the arch and $\frac{8}{5}\,QQ'$ for the right half. As these resultant depths differ but little for the two halves of the arch those for the left half will be taken for both. The earth pressure against the vertical planes through H and L will be ignored.

As a length of one foot of arch is being treated, the area on which each of those horizontal pressures acts is simply the height of vertical projection of each portion of the arch ring. The intensities of these pressures will be computed by the aid of equa-

tion (20) of the preceding Art. The elements of these pressures and the pressures themselves are:

			Areas	
$x_1 = 35.4$ ft.	$p = 10{,}620$ lbs.	$p' = 1{,}180$ "	15 sq. ft.	$h_1 = 159{,}300$ lbs. $h_1' = 17{,}700$ "
$x_2 = 23.3$	$p = 6{,}990$ "	$p' = 777$ "	10 "	$h_2 = 69{,}900$ " $h_2' = 7{,}770$ "
$x_3 = 15.8$	$p = 4{,}740$ "	$p' = 527$ "	5.5 "	$h_3 = 26{,}070$ " $h_3' = 2{,}900$ "
$x_4 = 11.3$	$p = 3{,}390$ "	$p' = 377$ "	4 "	$h_4 = 13{,}560$ " $h_4' = 1{,}510$ "
$x_5 = 8.2$	$p = 2{,}460$ "	$p' = 273$ "	2.5 "	$h_5 = 6{,}150$ " $h_5' = 680$ "

As a trial the following set of values were taken:

$$\left.\begin{aligned} h_1 &= 70{,}000 \text{ lbs.} \\ h_2 &= 30{,}000 \text{ "} \\ h_3 &= 14{,}500 \text{ "} \\ h_4 &= 7{,}500 \text{ "} \\ h_5 &= 3{,}300 \text{ "} \end{aligned}\right\} \qquad (22)$$

The conjugate or horizontal pressures given in (22) are to be combined with the weights $W_1, W_2, \cdots W_{12}$ so as to produce the resultant forces $1', 2, 3, 4, 5, \cdots 12'$, shown in magnitude and true position in Fig. 12, and in magnitude and direction only in Fig. 13. These resultant forces are laid down in Fig. 13 so as to form a force polygon $N, 1', 2, 3, 4, 5, 6, \cdots 12', K, P'$ in the usual manner with any convenient pole P'. Radiating lines are then drawn from P' to the angles of the polygon to find the trial frame. It was found, however, that h_1 was probably too small; it was, therefore, increased to 85,000 pounds for force 12 and 90,000 pounds for force 1. In the revised polygon, therefore, forces 1 and 12 take the place of forces $1'$ and $12'$, as shown in both Figs. 12 and 13.

The first attempt was to pass the trial frame, in Fig 12, through a''' at the crown and through the one-third points nearest the soffit in the springing joints ST and UV, but as that proved unsatisfactory it was determined to pass the trial frame through the three joints a''' (one-third $K'C$ from K'), a'' and a' the latter two points being about two feet each from V and S respectively.

This trial frame was started at a''' in the crown joint by drawing a line through that point parallel to $P'C$ and intersecting the lines of action of forces 6 and 7. From these two points of intersec-

tion the trial frame $b'ab''$, shown in broken lines, was constructed in the regular manner with sides parallel to the radiating broken lines drawn from P' in Fig. 13. The broken lines $a'd'$ and $a''e'$, Fig. 12, are drawn parallel to AB in Fig. 13 until they intersect R_1b' and $R_1'b''$ produced, thus locating the points d' and e' and determining the closing line $d'e'$ of the frame. $P'E$ in the latter figure is then made parallel to $d'e'$ in the former.

According to the principles established in Art. 12 every frame having its pole in the indefinite line $P'E$ may be made to pass through the two points a' and a'', but it remains to be determined which one of these will pass through the point a''' also. In Fig. 13 let there first be drawn the line BC, the closing line of the force polygon of all the forces between the springing joint ST and the crown; then let $a'b'$, Fig. 12, be drawn parallel to it until the line of action of R_1 is intersected, thus determining $b'a'''$. The line $P'D$, Fig. 13, is then drawn parallel to $b'a'''$ so as to fix the point D. From the latter point PD is drawn parallel to $a'a'''$ of Fig. 12 until EP' is intersected in P. The latter point is the pole of the desired polygon. Radiating full lines are drawn to the angles of the force polygon, Fig. 13, and the full line frame shown in Fig. 12 as passing through $a'a'''a''$ has its sides parallel to those radiating lines. The line of resistance is located by the intersections of the sides of this frame with the various joints of the arch ring. A close observation of Fig. 12 will show that the line of resistance lies wholly within the middle third of the arch ring. The stability of the arch is, therefore, established under the prescribed conditions.

A somewhat better line of resistance could be found by increasing the conjugate or horizontal pressures h_2 and h_3 without exceeding their maximum values. These changes would raise the centers of resistance in the joints ab and cd, as well as in fg to a less extent. The two reactions R and R' would be more nearly vertical. The construction made, however, conclusively demonstrates the stability of the arch ring, provided the load to which any joint is subjected does not exceed the safe working resistance of the masonry, and, further, that stability of friction is secured. The resultant force F_2, Fig. 13, acting on joint ab, is the largest in the diagram and its magnitude is 180,000 pounds. Hence the intensity of pressure in that joint is $180{,}000 \div 5.4 = 33{,}300$ pounds, which is within the safe limits of any masonry sufficiently excel-

lent for an arch ring. Again, the greatest obliquity of a resultant on any joint is that of R' on UV; but even that is too small to exert any prejudicial influence on the stability of friction. Hence the arch ring is shown to be abundantly stable in all particulars.

The thrust at the crown, PC, Fig. 13, determined by applying a scale to the diagram, is 174,000 pounds.

ART. 23.—GENERAL CONSIDERATIONS. The preceding methods are perfectly general and are applicable to any form of curve or to any manner of loading whatever. If the spandril is composed, either wholly or in part, of a series of small arches, as shown in Fig. 14, the load for that part of the arch ring over which the small arches are found will be wholly vertical and applied at the piers of the spandril arches.

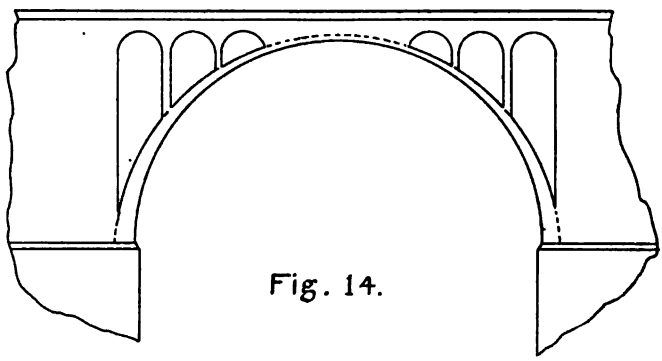


Fig. 14.

Whenever the loads are vertical that part of the force polygon representing them will be a vertical line. If there are no conjugate (usually horizontal) pressures there will be no means of such variations in the location of the line of resistance as result from the existence of those pressures. There will, however, usually remain some capacity of adjustment, but within narrower limits.

If pin joints are introduced at either the crown or springing joints, or both, as in some of the late foreign concrete or combined concrete and steel arches, the preceding methods are directly applicable, whatever may be the manner of loading. The pin centers are simply fixed points in the line of resistance through which the polygonal frame must pass precisely as the frames were passed through the assumed points, in the preceding cases, at the crown and springing joints. In the case of pin joints those points cannot be varied.

Obviously the largest drawings and diagrams practicable should

be used in connection with these methods in order that the highest degree of accuracy may be attained.

ART. 24.—DEFLECTION OF ARCH RING. The compression to which any arch ring is subjected under loading will necessarily shorten it and cause the crown (as well as all the other points in the ring) to settle or deflect vertically. Again if the abutments yield in a horizontal direction the crown and all points of the arch ring will suffer vertical deflection. Finally, the center of resistance is not in the center of figure of most joints and, hence, the arch ring will suffer some bending which will also produce deflection. These are stress effects due to loading which cause vertical deflections. Other vertical deflections will be induced by changes of temperature and by the contraction which cement mortar and concrete undergo while setting in air. The thermal effect will be

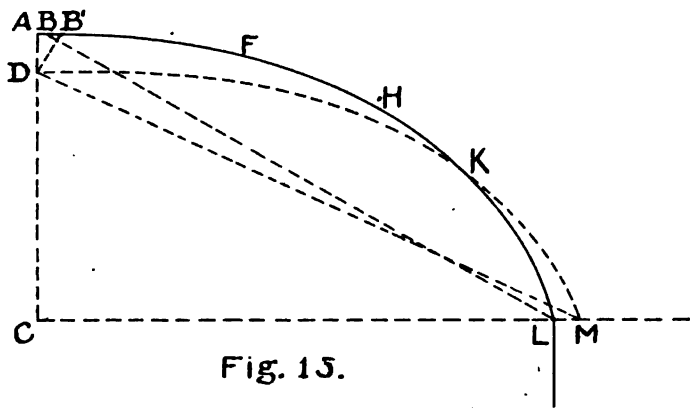


Fig. 15.

an increase or decrease in length of arch ring according as the temperature rises or falls. The last source of deflection is that arising from the fact that, when masonry (particularly concrete) is subjected to loading it suffers a permanent set in addition to its elastic deformation. This permanent set appears to depend upon the amount, frequency and number of applications of the load, although its precise relation to those elements of the problem has not yet been fully determined. Experiments on concrete indicate that the deformations become constant after a number of repetitions of stress that vary inversely as the ultimate resistance of the concrete and directly as the intensity of the applied stress.*

* "Properties of Concrete under Compressive Stress," by David Molitor, *Journal of Assoc. Eng. Soc.*, 1898.

The measure of this permanent set is sometimes called the modulus of permanent set. All these cases will produce horizontal as well as vertical deflections which may be determined by the same general methods applicable to the latter. The vertical deflections however, chiefly have practical importance and methods for their determination only and will be given. The bending effects will be disregarded since they do not play a relatively important part, and they can best be determined under that treatment of the arch which regards the ring as an elastic member.

In Fig. 15 the line *ABFHKL* represents the center line of any arch ring. Let that line be divided into any convenient or suitable number of parts of any lengths, the center line of any one of which does not vary materially either in length or inclination from its chord, as *FH*. Let l represent the total length of center line *AHL* of the arch ring while l' represents the length of any one of its parts, as *FH*. Let $\Delta l'$ be the variation in length of any one of these parts l' due to all the causes indicated, then the total variation in length of the entire center line *AHL* will be:

$$AB = \Delta l = \sum_{L}^{A} \Delta l' \qquad (23)$$

the length of the chord *BL* will then be, if the length of span be s:

$$BL = \sqrt{AC^2 + (CL - AB)^2} = \sqrt{v^2 + (\tfrac{1}{2}s - \Delta l)^2} \qquad (24)$$

The rise or versed sine of the arch, *AC* is represented by v and the span $2CL$ by s. If the abutment also yields horizontally by the amount $LM = \frac{1}{2}\Delta s$, the result will first be the movement of *B* to *B'* and then of *B'* to *D*, so that $DM = BL$ as given by eq. (24). The total distance *AB'* is so small that it may and will be considered parallel to *CL*. *DB'* will be essentially perpendicular to *DM*. The distance $DC = v'$ will then take the value:

$$DC = v' = \sqrt{DM^2 - CM^2}$$

$$= \sqrt{v^2 - s\Delta l + \Delta l^2 - \tfrac{1}{2}s\Delta s - \tfrac{1}{4}\Delta s^2} \qquad (25)$$

A close approximation will be:

$$v' = \sqrt{v^2 - s(\Delta l + \tfrac{1}{2}\Delta s)}. \qquad (25)$$

If the horizontal yielding of the abutment be ignored, *LM* in Fig. 15 will be zero, and the new position of the chord *BL* will be

DL, the point D having a somewhat higher position than before. The value of v' will then be:

$$v' = \sqrt{DL^2 - CL^2} = \sqrt{v^2 - s\Delta l + \Delta l^2} \qquad (26)$$

A sufficiently close approximation for all ordinary cases is:

$$v' = \sqrt{v^2 - s\Delta l}. \qquad (27)$$

The desired vertical deflection at the crown will then be:

$$w = v - v'. \qquad (28)$$

The vertical deflection of each of the other points F, H and K may be found in the same manner, but it is unnecessary. After the crown deflection $AD = v - v'$ is known, the new center line of the arch ring may be at once drawn by the aid of the new rise or versed sine CD and the half span CL or CM.

If the center line of an arch ring is circular, the radius has the value:

$$r = \frac{v}{2} + \frac{s^2}{8v}. \qquad (29)$$

If v becomes $(v - w)$ and s takes the value $(s + \Delta s)$ the new radius r' will be:

$$r' = \frac{v - w}{2} + \frac{s^2 + 2s\Delta s + \Delta s^2}{8(v - w)}. \qquad (30)$$

In all usual cases the term Δs^2 may be ignored in Equation 30. If the horizontal yielding of the abutments is not considered, $\Delta s = 0$ and Equation (30) will take the form:

$$r' = \frac{4(v - w)^2 + s^2}{8(v - w)} \qquad (31)$$

It will generally be impracticable to assign or determine the amount of horizontal yielding of the abutments, the influences producing such movements being too indefinite and complicated to permit of quantitative treatment. Hence it will not often be practicable to use those of the preceding equations which involve Δs.

On the other hand it is quite practicable to determine a fairly close approximation for the change in length of the arch ring. In finding that portion of the change in length due to the thrust along the ring it is to be remembered that that thrust, as shown by the radiating lines in Figs. 11 and 13, is not constant; although

in many cases it may be so taken without essential error. Again, the normal sections of the arch ring may not be constant in area at all points. When the thrust and the area of section cannot be taken as constant, the portions l' (AF, FH, etc., in Fig. 15) must be in such lengths that throughout each one both the thrust and area of section may be assumed to be constant; then if T' be the thrust, acting on the mean section a', of any portion l' and if E be the coefficient of elasticity for the arch ring, the total change in length due to the thrust in the ring will be:

$$\sum_{L}^{A} \frac{T'}{a'E} l' = \frac{1}{E} \sum_{L}^{A} \frac{T'l'}{a'} \quad (32)$$

In the determination of the variations in length of the arch ring the following notation will be used, it being borne in mind that both the coefficient of elasticity and modulus of permanent set vary with the intensity of applied loads:

a' = average area of normal section of arch ring in square inches, for length l'.

E = coefficient of elasticity in pounds per square inch for the intensity $T_1 \div a'$.

E' = modulus of permanent set in pounds per square inch for the intensity $T_1 \div a'$.

$\pm t^\circ$ = rise or fall of temperature in degrees Fahr.

α = coefficient of expansion per 1° Fahr.

ϵ = coefficient of shrinkage for mortar or concrete setting in air.

c = rate of compressibility of masonry, *i. e.*, shortening of one unit of length per 100 pounds per square inch.

T' = average thrust in arch ring for length l'.

The modulus of permanent set is a magnitude of the same kind as the coefficient of elasticity, *i. e.*, its reciprocal expresses the permanent set for one unit of length at the intensity of stress $T' \div a'$.

Tables I. and II. exhibit values of E and E' determined by Professor C. Bach, of Stuttgart, for concrete cylinders 3.28 feet long and .82 feet in diameter. The concrete was composed of Portland cement, sand and broken limestone, in the proportion of 1, 2½ and 5, and 1, 3 and 6. It was two to three months old only. The ultimate resistances were determined from the same cylinders, whose length, it is to be noticed, was four times the diameter. Cubes of the same area of section would probably have given 50 per cent. greater resistances.

TABLE I.

Values of Coefficient of Elasticity (E) for Concrete.

Ult. Resist. lbs. per sq. in.	Applied loads, lbs. per square inch.							
	114	142	213	284	355	427	497	569
853	3,243,000	3,172,000	3,044,000	2,901,000	2,745,000	2,574,000	2,432,000	2,318,000
1138	3,726,000	3,670,000	3,499,000	3,328,000	3,158,000	2,987,000	2,845,000	2,717,000
1422	4,210,000	4,125,000	3 954,000	3.783,000	3,623,000	3.470,000	3,342,000	3,186,000
1707	4,561,000	4,466,000	4,238,000	4,068,000	3,926,000	3,798,000	3,655,000	3,513,000
1991	4,835,000	4,736,000	4,509,000	4,310,000	4,139,000	3,982,000	3.840,000	3,698,000

TABLE II.

Values of Modulus of Permanent Set (E') for Concrete.

Ult. Resist. lbs. per sq. in.	Applied loads, lbs. per sq. inch.							
	114	142	213	284	355	427	497	569
853	17,494,290	16,783.140	14.649,690	12.942,930	11,520.630	10,240,560	8,960.490	7.751,535
1138	25,601,400	24,321,330	21,334,500	18,774,360	16,783.140	14,507,460	12,374.010	10,738,365
1422	35,557.500	34,135,200	29,868,300	26,739,240	23,894,640	20,765,580	18,489,900	16,498,680
1707	48,358,200	45,655,830	39,824,400	35,557,500	31,575,060	28,588,230	26,885,860	23,467,950
1991	62,581,200	59,594,370	51,202,500	44,944,680	39,539,940	35,557,500	32,428,440	29,868,300

All these values of E and E' are expressed in pounds per square inch for concrete of the composition and age indicated. They may have practical value for concrete arches under which the centers are struck at about the ages given. The tests were of laboratory material, and it is not impossible, in view of other tests of mortar and concrete made in this country, that the values of E, at least, are considerably too high for concrete arches as actually built. Although this subject lacks almost entirely the experimental treatment needed for quantitative determinations of strains for given stresses, it is quite possible that the values of E for actual concrete arches at least one year old may be found between 1,500,000 and 2,500,000 pounds per square inch.

The same lack of experimental data prevents the assignment of reliable values for the coefficient of elasticity (E) for cut masonry such as is ordinarily used in arch rings, and there are no data whatever for the determination of the modulus of permanent set (E) for the same grade of masonry. It is probably not far wrong to assume provisionally:

E = 2,000,000 to 3,000,000 lbs per sq. in. for best granite and limestone arch rings.

and E = 1,000,000 to 2,000,000 lbs. per sq. in. for less excellent arch rings.

Instead of using the two values of E and E', the coefficient c may be employed. It expresses the average rate of compressibility for each 100 pounds of applied load per square inch. Experiments made at the Watertown arsenal and reported in "Senate Doc. No. 35 First Session 49th Congress" yielded the following average values:

6, 8 and 12 inch cubes of neat Dryckerhoff Portland cement, 14½ to 22 months old:

$$\left.\begin{array}{r} c = .000{,}052{,}2 \text{ to } .000{,}082{,}6, \text{ with} \\ \text{average } c = .000{,}068{,}7. \end{array}\right\} \qquad (33)$$

8, 12 and 16 inch cubes of

$$\left.\begin{array}{l} \text{National Portland cement mortar, 1 cement, 3 sand;} \\ \qquad\qquad\qquad\qquad c = .000{,}062; \\ \text{“ “ “ concrete, 1 cement, 3 sand,} \\ \text{6 broken stone;} \\ \qquad\qquad\qquad\qquad c = .000{,}070{,}1. \end{array}\right\} \qquad (34)$$

Rosendale cement mortar, 1 cement, 1½ sand, $c = .000,138,1$.
Rosendale cement mortar, 1 cement, 3 sand, $c = .000,211,1$.
Rosendale cement concrete, 1 cement, 1½ sand, 6 broken stone, $c = .000,169,2$.
Rosendale cement concrete, 1 cement, 3 sand, 6 broken stone, $c = .000,210,4$.
Rosendale cement concrete, 1 cement, 3 gravel, 14 broken stone, 2 sand, $c = .000,172,9$. (35)

BRICK PIERS, 8″ x 8″, 16″ x 16″ and 12″ x 12″, 72″ to 120″ high
Age of piers, 15 to 24 months.

Brick.	*Mortar.*	
Bay State.	Portland, neat	$c = .000,073,5$
" " and Face	" 1 cement, 2 sand	$c = .000,113,1$
Common.	" " "	$c = .000,116,7$
Bay State.	Rosendale, " "	$c = .000,101,2$
" "	1 Rosendale cement, 2 lime, 6 sand	$c = .000,172$

(36)

The same brick piers with a mortar of 1 lime, 3 sand gave:

$c = .000,383,2$ to $c = .000,567,7$, with average $c = .000,495,4$. (37)

At the present time the coefficients of thermal expansion and contraction of different classes of masonry have been but meagerly determined. The following values of these coefficients (α), per degree Fahr., have been given or used by the authorities named:

Cement mortar (Bruniceau) ..... $\alpha =$ .000,005,56 to .000,007,78
Concrete 1 c., 2½ s., 5 stone (Bauschinger) $\alpha =$ .000,004,89
Concrete (Emperger) ..... $\alpha =$ .000,006,94
Rubble masonry of dams (Adie) ..... $\alpha =$ .000,005,56
Stone and brick (Bruniceau) ..... $\alpha =$ .000,002,95 to .000,004,61

(37)

Some of these values are doubtful and all may vary somewhat with the temperature, but they may be accepted until further and

better determinations are made. Inasmuch as the average value of a for iron and steel per degree Fahr. is about .000,006,6, it is obvious that combined structures of iron or steel and concrete may be assumed to expand and contract as units under variations of temperature.

Meagre determinations only have been made of the coefficient of shrinkage (e) of mortar and concrete which have set in air, but the following values have been found by Bauschinger and by a committee of the American Society of Civil Engineers (*Trans. Am. Soc. C. E.*, Vol. XVII.):

$$\left.\begin{matrix}\text{1 cement 0 sand}\\ \text{1 cement 3 sand}\\ \text{1 cement 5 sand}\end{matrix}\right\} \text{(Bauschinger)} \ldots e = \left\{\begin{matrix}.0012 \text{ to } .0034\\ .0008 \text{ to } .0015\\ .0008 \text{ to } .0014\end{matrix}\right\}. \quad (38)$$

$$\left.\begin{matrix}\text{1 cement 0 sand (Am. Soc. C. E.)} \ldots e = .0014 \text{ to } .0032\\ \text{1 cement 1 sand (Am. Soc. C. E.)} \ldots e = .0008 \text{ to } .0017\end{matrix}\right\} \quad (39)$$

The change in length of the portion l' of the arch ring, or the $\triangle l'$ of Eq. (23), can now be written as follows:

$$\triangle l' = -\left(\frac{T'}{a'E'} + \frac{T'}{a'E'} \pm t^{\circ}a + e\right) \quad (40)$$

or,
$$\triangle l' = -\left(\frac{T'c}{100a'} \pm t^{\circ}a + e\right). \quad (41)$$

The minus sign is used before the parenthesis because a shortening of l' is to be found. If t° is a rise of temperature the minus sign ($-t^{\circ}$) is to be taken and the plus sign ($+t^{\circ}$) if a fall of temperature is involved.

If the arch ring is of cut stone with thin joints the effect of the shrinkage of the mortar joints may be neglected. In that case $e = 0$ in Eqs. (40) and (41).

THE SILVER PICK MINE—WILSON, COLORADO.

By M. B. SPAULDING, E.M.

The San Juan region of southwestern Colorado has long been known as one of the most remarkable areas of igneous rocks of this country. Rugged and steep mountains rise to great altitudes and present extremely wild and imposing scenery. The region has received a large amount of attention from prospectors and with improved means of transportation, has developed into a very important producer of the precious metals. In many camps the mining is carried on at altitudes that are quite exceptional, and it is the purpose of this paper to give a brief sketch of one which presents many novel features.

San Miguel county has long been the seat of placer mining, but its deep vein mines are less known, if indeed one may speak of "deep" mines that are above the timber line The "Silver Pick" is one of a group of claims, owned by the Mt. Wilson Gold and Silver Mining Co. It is situated on a northwesterly spur of Mt. Wilson, and covers a vein that cuts through the spur, so that the highest drift, No. 1, at 13,700 feet above tide, goes clean through the mountain. The main tramming level is 700 feet lower, and at its mouth is the boarding house near the 13,000 foot contour. The timber line is about 11,000 feet above sea level, and the main peak of Mt. Wilson is 14,280, so that it is clear that the mining is carried on under conditions not often met. The claim is fifteen miles west of Telluride, and about eight miles southwest of the nearest station on the Rio Grande Southern Railroad. The mining districts of the locality are the Mt. Wilson and Lone Cone, but the Silver Pick is the only claim on which any amount of development has been carried on. It was located in July, 1882, and was patented in October, 1882. Since then it has been worked more or less continuously, at first in a small way, but in late years on a quite large scale. Somewhat over half a million dollars' worth of ore has been produced.

Topography and Climate.—The Mt. Wilson Mining District is considered to be one of the roughest and most precipitous parts of the Rocky Mountain system. No foothills are seen on the "mesas." The several peaks arise in groups directly from the tablelands, and the slopes are formed of slide rock and detrital gravels of granite

diorite and shale, which are covered by a dense growth of white spruce and quaking asps up to the timber limit, at about 11,000 feet altitude.

The results of volcanic eruption, of subsequent weatherings and of erosion are very strongly marked. The peaks are angular and sharp, and are connected, in their several groups, by serrated ridges.

The altitude of Mt. Wilson (Wilson Peak), as stated, is 14,280 feet, according to the U. S. Geological Survey, making it among the highest peaks in the United States outside of Alaska.

Numerous streams are found in the several basins, either flowing on the surface, during the summer months, or under the slide rock and of much smaller volume, during the winter. There are also several small lakes which could be utilized to store water for the winter for milling purposes. The walls of these lakes appear to have been formed by glacial action, and one can notice the moraines whose trend is parallel to the axis of the basin. Wherever the streams come to the surface rich grazing grass is found, and many flowers of delicate and varied color. Lichens cover the surrounding rocks.

The summer months are July, August and September. June is the spring month, although there is plenty of snow on the ground. From October to the last of May winter holds undisputed sway and is equal to any in the Klondike in the severity of its storms and cold. Some snow lies on the ground in shaded gulches and draws all the year round. At the head of Navajo Basin, which lies to the south of Wilson Peak and between the latter and Gorham Peak, is a natural glacier some 300 feet high, containing at its summit a small lake of some depth.

Geology.—The geology of this particular area has received passing mention from the parties of the national surveys that have worked in the region. W. H. Holmes* has given some notes and a profile sketch which includes Mt. Wilson (Plate XVI., l. c.). Whitman Cross has published a few notes on the character and petrography of Mt. Wilson and has reproduced a panoramic sketch by W. H. Holmes, of the mountains of southwestern Colorado, which includes this peak.† Professor Kemp has kindly furnished me

**Ann. Report, Hayden's Survey*, 1876. 193-195. See also Rep., 1875, Pl. XXXVI.

†*XIV. Ann. Rep. Div. U. S. Geol. Survey. Part II.* 203-206. Plate XIII. Cross reproduces Holmes' sketch of the Lone Cone, and reviews previous petrograph-

with the following notes on the microscopic characters of two samples of the emptives. No. 1, from Gorham Peak on the south side of Mt. Wilson, is a rather light colored granitoid rock, of somewhat coarse crystallization. The thin section shows abundant plagioclase and quartz crystals, with hornblende, biotite and augite. The augite is rimmed with hornblende. More or less magnetite is also present. The rock is a quartz-diorite, but the tendency of the component minerals to preserve their own crystal boundaries is marked, and indicates relationships with volcanic rocks. The observer cannot but infer that the rock in question is a deep-seated portion of a volcanic flow or else a laccolite. No. 2 came from the wall rock of a vein in the main base of Mt. Wilson. It has less quartz than No. 1, and is more finely crystalline. It is dark gray in color. The plagioclase tends to assume the rod-like character that is seen in diabases. Biotite is the chief dark silicate, but some other one has been present which is now decayed beyond recognition, but which was either hornblende or augite. Magnetite is abundant. The rock is a quartz-diorite of the same relationships as No. 1, so far as its occurrence is concerned.

The main cone of the Mt. Wilson eruption is granite, which is capped by a great diorite intrusion that forms the central peaks. There are also many granite knobs or bases which outcrop in the basins and which appear as spurs of the main peaks, but which are not capped by diorite. Even in the third or Boarding House level of the "Silver Pick" the writer has observed granite. On the south of Mt. Wilson the San Juan formation appears, and is the lower member of the volcanic complex. It consists of a series of andesitic tuffs and breccias. It rests unconformably on the San Miguel conglomerate, which latter contains in pebbles of varying size, granite, quartzite, limestone, schist, red sandstone and some porphyries. These two formations outcrop in small areas and are like the exposures near Telluride and Ophir Loaf, where they have been studied by Cross. The diorite overflow rests mainly on the granite, very little of it being in the Tertiary shales. The latter have a thickness of 1,500 to 2,000 feet and are easily recognizable along the sides of the deep canyons. Below the shales and conformable to them occurs the Cretaceous, in whose upper member,

ical notes. Cross has also described the general stratigraphy in the vicinity of Telluride, in *Proc. Colo. Sci. Soc.*, September, 1896, "The San Miguel Formation, Igneous Rocks of the Telluride District."

the Laramie, there are several small seams of fairly good, bituminous coal, still lower are the Jura-Trias "red beds" consisting of sandstone and conglomerate, and below this are found the Carboniferous hard, gritty sandstones and the blue limestone. At the upper contact of these quartzites and limestones occur the lead carbonate deposits of Saw-pit and other localities along the lower San Miguel river.

The diorite is a laccolite, or at least a deep-seated portion of an andesite intrusion, and as explored in the Silver Pick is very much faulted. In fact, the vein itself is on a crushed zone, which is very much shattered and split. As many as six or eight veins are found within a width of fifteen to twenty feet, some being more prominent than others. Where the crushed walls have been removed or replaced by the ore-bearing solutions, there the veins are thickest. All the veins contain mineral of some value. Some movements have taken place since the veins were at least partly formed, as is shown by slickensides and broken ground in the vein itself, or by faults which have thrown it from foot to hanging or *vice versa*. The vein matter may have been well-nigh eliminated by these movements.

The main or "Pick" vein has a strike of nearly northwest and southeast, and a dip, somewhat variable, but usually about 75 degrees. It varies in width from one inch to three feet, with an average of five to eight inches. The vein filling consists of pyrite, chalcopyrite, magnetite, arsenical antimonial iron compounds, and some lead and zinc sulphides. The gangue is quartz. It is a highly pyritiferous ore and probably came from a deep-seated source, as shown by its occurrence in the diorite. The gouge is very small in thickness, but is strongly marked, especially in the main vein.

When the quartz forms "vugs" in the vein the space is usually filled with ice, even at a distance of over 300 feet from the nearest outcropping. In many places, where the surface water percolates, copper and iron sulphates and copper oxide are formed; the former, redepositing in amorphous layers and crystals. Only in August does any water seep into the mine; during the remainder of the year the ground is frozen solid. When the water seeps through, and is exposed to the air in the drifts and stopes, it freezes and forms stalactites and stalagmites, which must be frequently cut out in order to keep the tracks open.

The main value of the vein is in gold, largely in the free state,

but so coated and oxidized that amalgamation is impracticable. Straight concentration is therefore employed.

Mining.—The mine is opened up by 7 drifts or levels—varying from 50 to 200 feet apart and they are all connected by manways. The highest level, No. 1, goes through the mountain and is some 450 feet long. It is about 150 feet from this level to the apex of the vein. The lowest level, No. 7, is some 125 feet below the main tramming level, at which the wire rope tramway terminal and boarding house are situated—at an altitude of 13,000 feet—whilst No. 1 is 13,700 feet.

Single-hand drilling in overhand stopes is the method of mining adopted throughout, except in driving drifts, where double-hand work is found to accomplish more. As already stated, on account of the altitude and hard character of the rock, the work done per man per shift is very small. Sometimes as many as 23 drills are dulled, without a broken steel, to put in a hole nine inches deep.

With the vein averaging only five inches in width it takes an ore value of from $25 to $30 per ton to pay expenses. The cost per ton for supplies averages close to $2.50. It requires about 7 shifts, at $3.00 per shift, to stope a fathom square of ore, which will weigh about 1¼ tons for a thickness of five inches. The cost of mine tramming and transportation by aerial tramway to mill is another dollar per ton.

The ore is stripped and broken down on bulls' hides. Both the broken ore and waste are handled in the stopes in small boxes and through mill holes to the level below. The excess of waste goes to the dumps at the different levels and the ore is sent on down to the main tramming level.

The aerial tramway has a capacity of 40–45 tons per day—of 10 hours—or 600 to 675 buckets, of 130 pounds each.

Milling.—The mill having been remodeled from an ore house is not conveniently situated, nor does it handle economically either the ore or product. It averages about $2.00 per ton of ore crushed, but it does exceptionally good work in the saving of values: from 85% to 90% of the gold and 60% to 65% of the silver of the crude ore are obtained. The concentration averages about 3½ into 1 for clean ore. For the general run of the mine it hardly pays to sort close in the stopes, and the concentration will run up to 8 into 1, though without increasing the values. The concentrates really represent the clear vein matter, so that the

assay of pure ore usually shows the value of the concentrates. When near the surface, however, the concentration is higher from the vein matter alone, and the values increase.

The value of crude ore averages from 2½ to 3½ ozs. gold, 20 ozs. silver and 5% Cu. The average concentrates will run about 4½ ozs. gold and 18–20 ozs. silver and 1.5 % to 4.5% copper, the loss in copper being due to the soluble sulphates. Silica in the concentrates is low—12% to 15%, and iron is high, 31% to 37%, so that treatment charges are low, rarely over $3.00 per ton, but the freight on this class of ore is high, $10.00 per ton to Denver or Pueblo—from Wilson (or Telluride).

The capacity of the mill is from 35–40 tons per twenty-four hours for the ten stamps—crushing through 24-mesh brass wire screen. The stamps are 650 pounds, 6-inch drop, and 95–100 drops per minute.

The crushed ore from each battery goes to a set of three Brown's sizers, and thence to a set of three vanners. The coarse ore is treated on a four-foot corrugated belt improved Frue vanner, having a five-inch fall and making 200 revolutions per minute. The middlings and slimes pass to six-foot smooth belts, improved Frue vanners, having falls of 1¼ inches and 3 inches, and making 180 to 190 revolutions per minute.

The tailings then pass to a canvas concentrating plant of nine tables, making an average product, as washed from the tables of 0.70 ozs. gold and 9 oz. silver per ton, with 30–35 % silica. This on being redressed on vanners yields a product of 3–3¼ ozs. gold, 20 ozs. silver and 14%–16% silica, which is shipped to the smelter with the main product. Owing to the corrosive action of the large amount of soluble sulphates in the ore, the mortars have to be made of extra thickness. All iron work and pipes rapidly corrode.

Situated as the mill is, just *above* the confluence of three forks of Bear Creek, it is at a disadvantage during the winter months with respect to water supply; indeed even for sufficient to run the six vanners, without the boiler, etc. It is thus necessary to catch the tailing water and pump it back for the use of the batteries. Snow has been melted to obtain water for the vanners.

The large capacity of the mill is due to the friable ore, and most of it because it carries sulphates slacks, after being broken in the mine, and when it reaches the mortars it rapidly disintegrates, even before being crushed.

The fuel used for the boiler is quaking asp, which costs per cord laid down at the mill $2.50. The number of cords required per 24 hours, for 10 stamps averages about seven. This wood makes good steaming fuel, when cut green, and dried about six weeks—so that the outside is dry and the heart green—or nearly so. It is cheaper than soft coal on account of high freight charges.

When the mill is running full time and producing the average grade of concentrates—a car of 10 to 11 tons is turned out every 48 hours—with a gross monthly output of about $25,000.

NOTES ON TELEGRAPHY AND TELEPHONY.

By W. H. FREEDMAN, E.E.

History of Telegraphy.

Telegraphy is the art of conveying intelligence to a distance by signs or sounds. The first telegraph may be said to have consisted in the lighting of fires which the ancients employed to announce the approach of an enemy.

The ancient Greeks used a method which, although tedious and slow, still allowed of the actual transmission and easy interpretation of messages. Towers were erected at suitable distances apart and in sight of each other. In each one of these towers was a vessel with the letters of the alphabet marked down the side. Each vessel would hold a certain quantity of water and was so arranged that its contents could be discharged at a definite rate. When one station desired to transmit a message to another, a torch was raised at night. A similar answering signal meant that the receiving station was ready. At another signal the water was allowed to flow out of both vessels. When the level of the water had fallen opposite the proper letter, the torch was again raised. This was the signal for the attendant at the receiving tower to note the letter to which the level of the water in his vessel had fallen; this of course being the same as in the sending tower.

The first method of telegraphy that obtained any extended application was the semaphore system, which was introduced in the latter part of the eighteenth century and used throughout Europe, especially in France and Russia. This system consisted in having

one or more movable arms attached to vertical posts. By changing the relative positions of these arms according to some fixed code, messages could be transmitted quite rapidly. A telegraph of this class was used at one time between Sandy Hook and the Custom House in New York City to acquaint the officials of the arrival of vessels. In a modified form it is in use on every railroad to-day.

Two other methods of visual telegraphy that are still in use, are heliography and the various signalling systems as employed by military and naval organizations. In heliography, flashes of light are thrown from the surface of a plane mirror. Each letter of the alphabet is represented by a particular number of flashes to the right, to the left or by a combination of flashes to right and left. Interrupting the light, the message may also be read from the relative durations of the flashes or by the intervals between successive flashes.

The signalling system employed by the war and navy departments throughout the world employs codes of motions of flags or torches. This is technically called wig-wagging.

The method, however, in almost general use to-day, for the transmission of the immense number of messages rendered necessary by the greater commercial activity, is the Morse system in one form or another. Although this system was invented by Professor S. F. B. Morse in 1837, electrical means had been used, experimentally, many years previous for conveying intelligence to a distance.

Lesage, of Geneva, as early as 1774, devised an electric telegraph which employed twenty-four insulated wires. Each of the twenty-five letters of the French alphabet had its own wire except i and j for which only one was used. A pair of pithballs were suspended from each end of each wire. Electrifying any particular wire by connecting it with a static machine caused the corresponding pithballs to diverge and thus indicated the letter transmitted. In 1787 Lomond, of Paris, succeeded in telegraphing in a similar way by means of only one wire. This he accomplished by using a different number of divergences of the pithballs to represent the various letters. Cavallo, of London, in 1795, and Salva, of Madrid, in 1798, employed the sparks from a Leyden jar, the letters and signals being made by counting the number of sparks sq sent before a pause.

Francis Ronalds, of London, in 1816, invented a system in which two dials rotating in unison and operated by clock work were used at each end of a wire. Each dial had a notch cut in it and rotated in front of the letters of the alphabet placed in a circle. When the notch was opposite the proper letter the wire, which was kept electrified thus causing the pith-balls to diverge, was discharged and instantly the pith-balls collapsed. The distant observer was thereby informed to note the letter seen through the notch of his dial. Nothing practical, however, ever resulted from these attempts on account of the numerous inherent difficulties in such a system.

Volta's discovery in 1800 of the generation of electricity by chemical means, followed in the same year by that of Nicholson and Carlisle in decomposing water, furnished the fundamental principles on which Sömmering, of Munich, in 1809 based his telegraph. He liberated hydrogen and oxygen in a series of voltameters, each corresponding to a certain letter or number and having its separate circuit. In consequence of the expense resulting from the use of so many wires and the slowness of its working, this telegraph was never practically used. In 1810 Dr. J. R. Coxe, of Philadelphia, proposed the same system and later conceived the idea of telegraphing by the decomposition of metallic salts. This idea was the basis of the system patented by Edward Davy, July 4, 1838. Alexander Bain, of Edinburgh, in 1846 patented a system the receiver of which made use of a chemically dampened tape upon which, by the action of the current passing through it, would be recorded marks of varying length depending upon the time the circuit was closed at the sending station. Although chemical receivers have been employed quite often, they have generally been supplanted, so that at the present time their main point of interest lies in their possible re-introduction with rapid machine telegraphy.

The discovery by Oerstedt in 1820, of the action of an electric current in deflecting a magnetic needle, was almost immediately followed by attempts to utilize it for telegraphic purposes. The idea of using suspended magnetic needles surrounded by coils of wire, in the place of Sömmering's voltameters, was suggested by Ampère in the same year. In 1832 Schilling, of Cronstadt, proposed a system the models of which were exhibited before the Russian Emperor. He proposed to employ only two wires (one circuit), and a single multiplier with a magnetic needle. By means of appropriately arranged combinations of the right and left deflections

of the needle, he was able to form all the characters necessary for correspondence. Independently of these experiments the German professors, Gauss and Weber, in 1833 actually constructed a telegraph on practically this plan. They ran a two-wire circuit from the Physical Cabinet to the Astronomical Observatory of Göttingen, a distance of about 6,000 feet. Galvanometers with telescopes and scales formed the receivers, while the transmitters were coils of wire surrounding permanent magnets; by moving the coils, electric currents were induced. This seems to be the first electric telegraph that had an actual existence for several years. It was in use until 1838 and was later destroyed by lightning.

In 1837 Cooke and Wheatstone, of London, brought into practical application the first form of their needle telegraph. This employed originally five needles which, counting the return wire, required six line wires, but was afterwards modified to a single needle and only two wires (one circuit). Needle telegraphs have been used extensively in Europe, especially in England and France, although now rapidly becoming replaced by Morse apparatus.

In 1820 Arago and Davy independently showed how to magnetize pieces of iron and steel by inserting them into spiral coils of copper wire around which a current was circulating. Following these experiments Sturgeon produced the first practical electromagnet in 1825.

From 1828 to 1832 Professor Joseph Henry, of Albany Institute and afterwards of Princeton University, performed his now famous experiments with electromagnets. He was the first to wind more than one layer on the iron core and thus become able to produce any appreciable magnetization at a distance. In 1831 he transmitted signals by sounding a bell. These signals were produced by the polarized armature of an electromagnet which was made to vibrate by the reversal of the current and strike the bell. In this connection it must be remembered that Ohm only announced his law in 1825, that his complete book on The Electric Circuit was not published till 1827 and that this work was not translated into English until 1841.

On September 2, 1837, Morse gave the first public exhibition of his telegraph, based on the action of electromagnets. This is the system which, more or less modified, has supplanted all others.

His first ideas seemed to have taken form in 1832, while on board the ship Sully, returning from France. In perfecting his

system so it became a practical and commercial success, he received much assistance in the form of scientific advice from Professor Leonard D. Gale, who was familiar with Henry's work. Alfred Vail also rendered very material assistance in the form of financial aid and by his mechanical ingenuity. The fundamental idea, however, of employing electromagnets is original with Morse independent of Henry's suggestions.

In 1837 Professor Steinheil constructed and put in use his registering electromagnetic telegraph between Munich and Bogenhausen. By the deflection of a needle he produced dots on a moving strip of paper to stand as signals for letters, the paper being drawn forward by clockwork, in an endless ribbon. He discovered that instead of a return-wire the earth might be used, contact being made to earth at the two ends by means of earth plates sunk in the ground. He was making some experiments on the Nürnberg-Fürther railroad for the purpose of determining whether the track could be used for telegraphic purposes when he noticed that the current passed from one rail to the other through the earth. This suggested dispensing with the return-wire.

Shortly after the establishment of the telegraph the inconveniences and expense arising from the multiplication of wires proved so serious that it became urgently necessary to adopt measures of relief. The efforts to devise remedies led to the invention of systems of multiple telegraphy, in which the same conductor might be used for the transmission and reception of more than one communication at the same time. The possibility of making use of a single wire for the simultaneous transmission of two or more communications seems to have first suggested itself to Moses G. Farmer, of Boston, about the year 1852. He proposed to employ two rapidly revolving synchronous commutators, one at each end of the line, which would serve to bring the latter successively and simultaneously into connection with two or more short branches at each terminus in each of which ordinary telegraphic apparatus might be inserted. Thus the current in the corresponding branches at either stations, though apparently continuous, would actually be composed of rapidly recurring synchronous pulsations.

In 1853 Dr. Wm. Gintl, Director of the Austrian State Telegraphs, invented a system of duplex telegraphy which allows of two simultaneous messages in opposite directions. The duplex systems in most general use to-day are those of Joseph B. Stearn,

invented in 1870, and the polar duplex, based upon Frischen's suggestion in 1863.

In 1855 J. B. Stark, of Vienna, succeeded in sending two messages in the same direction, inventing diplex telegraphy. Diplex as used to-day, and forming the basis of the quadruplex, was invented by Thomas A. Edison in 1873. This same year Heaviside, of London, invented a quadruplex, although the methods adopted were invented by Edison in 1874.

Multiplex telegraphy higher than four simultaneous messages over the same wire is not commercially employed to any extent, although such systems exist as, for example, Gray's Harmonic Telegraph, Delany's Synchronous Multiplex and certain methods employing alternating currents of different frequencies. An automatic telegraph, patented by Wheatstone in 1858, in England, is in use extensively in that country and to a limited extent in France, Italy and the United States.

The perfection to which the electric telegraph has been brought can be imagined from the average working speed that is attained:

Simple Morse	15	words	per	minute.
Duplex Morse	36	"	"	"
Quadruplex	60	"	"	"
Simple Wheatstone	125	"	"	"
Duplex Wheatstone	200	"	"	"

The highest speeds ever attained seem to be 52 words per minute by simple Morse and 450 words per minute by the Wheatstone automatic. With a view to ascertaining the highest speed at which telegraphic characters can be legibly recorded, Mr. P. B. Delany in some experiments has succeeded in transmitting by his machine system 8,000 words per minute and obtained a plain reproduction of the signals by electrolysis on the chemically prepared receiving tape. The circuit was an artificial one of 650 ohms and 2.95 microfarads, being about the equivalent of an ordinary telegraph line of 100 miles in length. The electromotive force was 115 volts. At this speed the perforated tape upon which the messages were composed passed through the transmitting machine at the rate of 27½ feet per second, and the impulses comprising the letters traveled at the rate of 2,500 per second.

The extent to which the telegraph has grown is shown by the fact that at present, 1898, there are very close to five million miles of

wire used for telegraphic purposes in the world, about one million being in the United States alone, and the estimated capital invested in the United States in the telegraph is about 150 million dollars. Mr. F. W. Jones, in the *Electrical World* of January 2, 1897, says that, excluding Canada, Central and South America, there were in the single year of 1890 sent more than 231 million messages throughout the world.

For further study of the general history of telegraphy, the reader is referred to the following: The American Electromagnetic Telegraph, by Alfred Vail, Philadelphia, 1845. The Electric Telegraph, its History and Progress, by Edward Highton, London, 1852. Historical Sketch of the Electric Telegraph, by Alexander Jones, New York, 1852. The Electric Telegraph, by Robert Sabine, London, 1867. Electricity and the Electric Telegraph, by George B. Prescott, New York, 1888. Electricity and Magnetism; translated from the French of Amédée Guillemin, revised and edited by S. P. Thompson, London, 1891. American Telegraphy, by William Maver, Jr., New York, 1892. The Invention of the Electromagnetic Telegraph; a series of articles of this title in the *Electrical World* of 1895, by F. W. Jones, on July 20th, F. L. Pope on August 3d, J. J. Fahie, August 24th and Rudolph Petsch, September 7th.

Systems and Codes.

Any telegraph system using the electric current, in order to properly transmit messages, must embody the following essential elements:—

1. An electrical generator or source of electrical energy.
2. A conducting circuit or path directing the energy from place to place.
3. A transmitter or means for controlling the energy employed.
4. A receiver or means for indicating or recording the signals.

All practical electrical telegraphs depend upon either the magnetic or chemical effect of the electric current for the production of the signals employed. The signals produced are either visible or audible. Visible signals, again, may be either evanescent or permanent. The evanescent visible signals are those used by the various needle and dial telegraphs of Great Britain and Europe proper, as well as the deflections of the mirror galvanometers used in long submarine telegraphy. The permanent visible signals are

either the showing of a number or letter in an annunciator or else records made:—

1. By means of ink on a moving strip of paper as in the Wheatstone automatic system, siphon recorder, or ink-writing register.

2. By the electrolytic action of the current on a chemically prepared tape.

3. By a stylus making indentations in, or embossing a strip of paper.

4. In printing telegraphs, by type-wheels actually printing the message.

Audible signals are made by a lever striking a bell or a metallic stop, mounted in such a way that the base of the instrument amplifies the sound like a sounding board.

The character of the signals with the respective receiving instruments employed in the various systems are shown in the following classification:

Character of Signals.		Systems.	Receiving Instruments.
Visible	Evanescent	Needle	Vertical Galvanometer.
		Dial	Pointer on dial.
		Long submarine work	Mirror Galvanometer.
	Permanent	Ink recording on tape	Wheatstone.
			Register.
			Siphon Recorder.
		Electrolytic	Chemical.
		Embossing on tape	Register.
		Printing on tape	Type wheel.
		Call or alarm	Annunciator.
Audible	Not permanent	Morse	Sounder.
		Call or alarm	Bell.

With the exception of printing and dial telegraphs the signals for transmitting messages are sent according to some specified code. The codes employed with very few exceptions are either the Morse or the Continental. In both of these the letters and characters are composed of dots, dashes and spaces. These are formed by the length of time during which the key or other transmitting instrument, may be held closed or open, the time of making a dot being taken as unity. The length or duration of a dash is equal to three units, while the spaces have the following values:

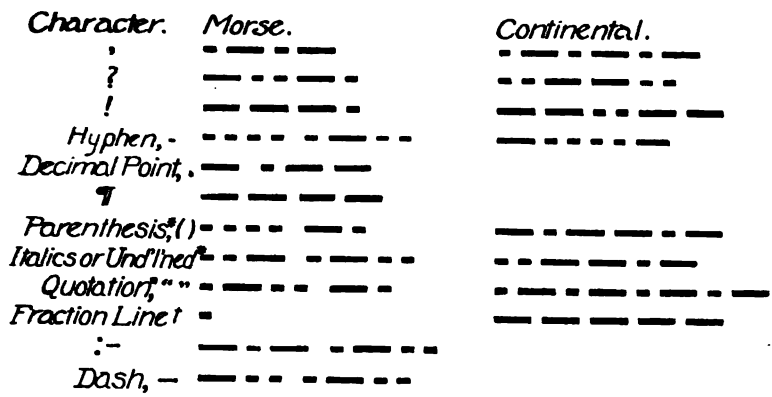
The space between the elements of each letter,	1 unit.
The space between two letters,	3 units.
The space between two words,	6 units.

Alphabet.

Letter.	Morse.	Continental.
A	·—	·—
B	—···	—···
C	—·—·	—·—·
D	—··	—··
E	·	·
F	··—·	··—·
G	——·	——·
H	····	····
I	··	··
J	·———	·———
K	—·—	—·—
L	·—··	·—··
M	——	——
N	—·	—·
O	———	———
P	·——·	·——·
Q	——·—	——·—
R	·—·	·—·
S	···	···
T	—	—
U	··—	··—
V	···—	···—
W	·——	·——
X	—··—	—··—
Y	—·——	—·——
Z	——··	——··
&	·—···	

Numerals, Punctuation, Etc.

Character.	Morse.	Continental.
1	·————	·————
2	··———	··———
3	···——	···——
4	····—	····—
5	·····	·····
6	—····	—····
7	——···	——···
8	———··	———··
9	————·	————·
0	—————	—————
Period, .	·—·—·—	····——
:	———···	———···
;	—·—·—·	—·—·—·



In the Morse code there occur the "spaced" letters C, O, R, Y, Z and &, which are distinguished by a space in the body of the letter equal to two units.

In permanent signals these dots and dashes are marked by ink or are due to the electrolytic action of the current on the moving strips of paper in the receivers. In needle telegraphs the deflections to the left correspond to a dot and deflections to the right to a dash. In the Morse system proper a dot gives a short, sharp click, the down and the up stroke of the lever being merged into one sound, while a dash being of longer duration the two sounds are distinct.

The Morse and Continental codes showing the letters, numerals and principal punctuation marks employed in each, are given above.

Generators.

The generators employed in telegraphy were originally some form of primary battery, but as the number of lines increased and the storage battery, the dynamo and the dynamotor were perfected they also were employed in the terminal stations, so that to-day the primary batteries, in this country at least, are fast becoming restricted to "way stations."

Primary Batteries.—The very first generators used in telegraphy were the old batteries of Bunsen and Daniell. The Bunsen cell is a zinc-carbon couple in which the elements are immersed respectively in dilute sulphuric and strong nitric acids separated by a porous cup. It has the fatal objection of emitting corrosive fumes,

* To be placed before and after the words to which it applies.

† To be placed between the numerator and denominator of a fraction.

due to the chemical reactions going on when current is drawn. This very soon led to its being discarded. To do away with the fumes and to preserve the amalgamation of the zinc, the Bunsen cell has been modified by Fuller. In this form the zinc is placed in the bottom of the porous cup where it is covered by a layer of mercury. The cup is then filled with water and placed in a jar containing the carbon plate immersed in a diluted solution of bichromate of potash and sulphuric acid. The acid by diffusion through the cup acts upon the zinc. This cell is frequently employed where a strong current is required and is in extensive use in Great Britain.

The Daniell cell is a zinc-copper couple in which the electrodes are in dilute sulphuric acid and a saturated solution of copper sulphate. This has the serious defect of the copper sometimes depositing upon the porous cup instead of the copper plate. This deposit grows in the pores, fills them up and finally cracks the cup, thus rendering the cell inoperative. To remedy this defect the Daniell cell has been modified into various forms of gravity-cell, thus eliminating the porous cup and depending upon gravity alone to prevent the diffusion of the solutions which must therefore be kept at sufficiently different densities. The principal forms are the Meidinger used in Austria and Germany, the Callaud used in France and the Gravity or Crow-foot used in this country.

In the Gravity or Crow-foot cell the copper is the lower plate and is surrounded by crystals of copper sulphate. The zinc or crow-foot is hung above, in a weak solution of zinc sulphate. Briefly stated it has the following advantages over the Daniell :—

1. It has no porous cup.
2. It is of lower first cost.
3. It has a lower internal resistance.

This cell, however, should only be used on circuits where the action is sufficient to use up the copper sulphate as speedily as it is dissolved, otherwise the solutions will eventually mingle and the copper of the sulphate be deposited on the zinc as a black mud. This will not happen in closed circuit working. Also, as the water evaporates, the zinc sulphate crystallizes round the jar and then creeps up by capillary action, crystallizing as it ascends, till it finally flows slowly over the top, creating a disagreeable nuisance. If the evaporation continues long enough, the level of the liquid sinks below the zinc crow-foot and the circuit is even-

tually opened. Both evaporation and creeping can be prevented by floating a layer of good quality of lubricating oil on top of the zinc sulphate. If the use of oil is objected to, on the score of fire-risk and the greater labor and care required in cleaning, then the creeping can still be prevented either by dipping the jar before setting up into a bath of melted paraffin to the depth of about half an inch, thus forming when cold an adherent and repellent coating, or pasting round the rim, inside and out, a strip of adhesive tape. Without the use of oil, evaporation can only be successfully remedied by continued refilling of the jar.

Another form of cell that has found favor in closed circuit working is the Edison-Lalande. Its elements are amalgamated zinc and protoxide of copper, while the exciting agent is a solution of oxide of potassium or caustic potash. The hydrogen liberated from the water combines with the oxygen of the copper oxide, reforming water and depositing pure metallic copper. Protoxide of copper is obtained by roasting copper turnings. The product is then ground to powder and compressed into solid masses from which are cut plates of suitable size for the cell. Oil is always used in this cell, it being claimed that it not only prevents evaporation and the formation of creeping salts but also the combination of the carbonic acid gas of the air with the potassium of the solution. The Edison-Lalande cell has the advantage of a very low internal resistance of only a few hundredths of an ohm, thus giving it a large current capacity. Its E. M. F., however, is low, being only about 0.7 of a volt.

For open circuit working the cell employed, especially in France, is one of the many forms of the Leclanché. This is a zinc-carbon couple the elements of which are used in a solution of sal-ammoniac and a finely divided layer of black oxide of manganese respectively. Some forms use a porous cup, others do not. If the liquid is allowed to become supersaturated by evaporation, a double salt of the chlorides of zinc and ammonium is liable to crystallize on the zinc. This reduces the E. M. F. and increases the internal resistance. A small quantity of hydrochloric acid will usually dissolve these crystals. If the cell is left undisturbed for some time, it will be found that the zinc rod is eaten away at the surface of the liquid, and that it is conical in shape, with the larger end of the cone at the bottom of the zinc. The excessive waste at the surface is doubtless due to oxidation, but the coning is the

result of local action.* The double chloride of zinc and ammonium gradually settles to the bottom of the cell, becoming denser and denser as the bottom is approached. Now zinc in a solution of ammonic chloride is positive to zinc in zinc chloride; if the latter liquid contains ammonic chloride also, the resulting E. M. F. is smaller but still appreciable. Hence local circuits are formed between the upper and lower portions of the zinc rod, the upper portions playing the part of the zinc in a simple voltaic combination.

Storage Batteries, also, and perhaps more properly called secondary batteries or accumulators, consist of cells in which a chemical change is brought about by passing a current through them, after which when connected in any electric circuit they give back electrical energy until they return to their original chemical condition. In other words, the "charging" current produces a chemical change increasing the chemical potential energy in the cell. After the cell is charged it may be looked upon as a primary battery, for in discharging it allows the chemical energy to be transformed into electrical energy. Any primary battery will act as a storage battery provided its chemical action is reversible. The Daniell or gravity battery, for example, may be regenerated by sending a current through it opposite in direction to that produced by it. The zinc sulphate and metallic copper are thus reconverted into metallic zinc and copper sulphate. The copper-zinc primary battery of Lalande and Chaperon or the form given to it by Edison, being reversible in action, can be used as a storage battery. In this cell, when discharged, the positive plate has become porous copper and the electrolyte a solution of potassium zincate; while upon charging it, metallic zinc is deposited, the porous copper is reoxidized and the liquid returns to caustic potash.

Innumerable forms of storage batteries have been invented in which copper, zinc and other metals besides lead were used; but almost all of those now being manufactured are lead batteries of the Planté or Faure types, or a compromise between the two.

The storage battery was first employed in telegraphy by S. D. Field, in San Francisco, in 1878. It was introduced into England about 1886. The principal storage battery used in telegraphy is

* Primary Batteries by H. S. Carhart.

the Chloride Accumulator manufactured by the Electric Storage Battery Company of Philadelphia. This is a lead cell using sulphuric acid and water as the electrolyte. For complete information regarding its actions and processes of manufacture the reader is referred to the list at the end of this chapter.

Dynamos and Dynamotors.—The first successful application of the dynamo as a generator in telegraphy was also made by Field, in San Francisco, in the year 1879. The method he adopted, for obtaining the different E. M. F.'s according to the requirements of the different lines, is shown diagrammatically in

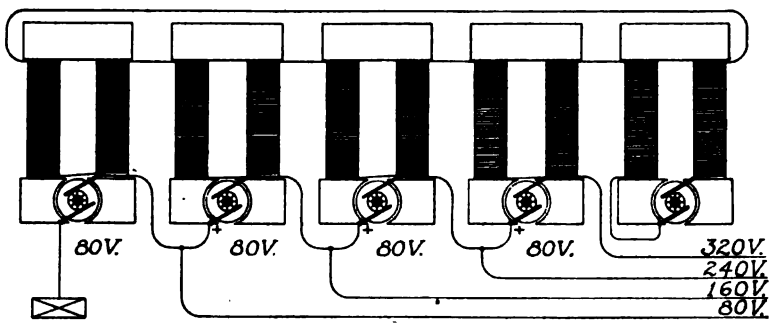


FIG. 1. S. D. Field Arrangement.

Fig. 1. He used four separately excited machines each giving eighty volts and a series machine to feed their fields. This arrangement furnishes four-line voltages of respectively 80, 160, 240 and 320 volts while requiring five machines. The present arrangement employed at the Western Union building in New York is shown diagrammatically in Fig. 2. This also employs five machines but furnishes five-line voltages of respectively 70,

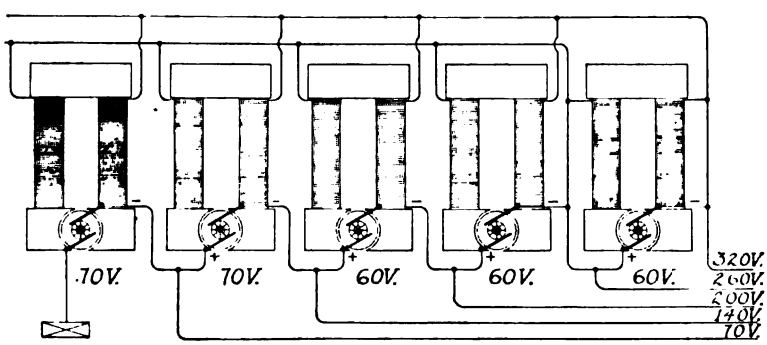


FIG. 2. Western Union Arrangement.

140, 200, 260 and 320 volts. This is accomplished by the fifth machine being shunt wound and furnishing a line voltage of 60 besides feeding the other four fields in parallel, while the voltages of the other four machines are 70, 70, 60 and 60.

Up to about 1893 the dynamo used in telegraphy was belt driven, a fair example of the practice being shown in Fig. 3. With the development of rotary transformers or dynamotors the belting was entirely eliminated, thus increasing the efficiency of the plant. A dynamotor consists of a motor and dynamo com-

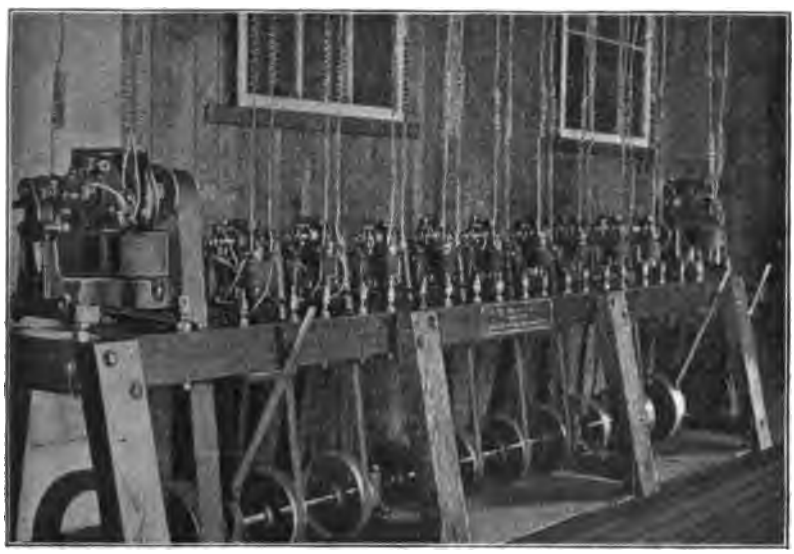


FIG. 3. 11 Dynamos. Western Union Telegraph Co., New Haven, Conn. 1892.

bined, the former being driven by the current from the main or primary circuit, and the latter generating the current for the secondary or in this case the telegraphic circuit. By proper design the dynamo delivers any voltage desired, independent of the voltage of the primary or motor circuit. In most cases the two armature windings are placed on the same core and are acted upon by the same field magnet, as illustrated in Fig. 14. Each machine is thus seen to be entirely independent and furnishes the proper voltage for a number of lines connected in parallel. This method is best illustrated by the plant of the Postal Telegraph Co., at its main office in New York, shown in Fig. 5.

In order to reduce the number of machines in large terminal

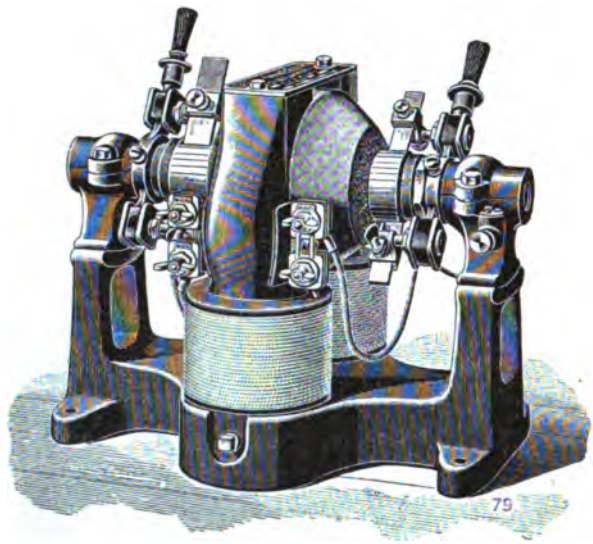


FIG. 4. Dynamotor.

stations attempts have been made to set a number of brushes around the commutator and thus make a multi-circuit machine of an ordinary dynamo with a single armature winding and commutator. As the currents drawn are only a small fraction of an

FIG. 5. 25 Dynamotors. Postal Telegraph Co., New York. 1894.

ampère per line the sparking is overcome by using a double brush with a resistance between the parts. A dynamo arranged in this manner is described in the *Electrical World* of June 9, 1894.

Relative Advantages.—Any comparison of the different kinds of generators results in bringing out the fact that storage batteries as well as dynamos and dynamotors would in all cases be chosen for terminal stations before the gravity cell which at one time you might say was the standard cell for telegraph work in this country. A gravity cell has an E. M. F. of 1.079 while its internal resistance is approximately 2 ohms. This gives so high an internal resistance that only three or four lines can be worked in parallel from the same battery. Chloride cells have an E. M. F. of about two volts and an internal resistance of only a few thousandths of an ohm. This, therefore, necessitates practically only one-half the number of cells for the same line voltage, while a great many lines can be worked in parallel from the same battery. The number of chloride cells of various capacities with the number of gravity cells displaced in several Western Union offices, is shown by the following figures: At New Orleans 843 chloride cells displaced 7,000 gravity cells, at Washington 724 chloride cells displaced 7,300 gravity cells, and at Atlanta 688 chloride cells displaced 8,000 gravity cells. In July, 1895,* the Western Union Co. used in its various offices 3,116 chloride cells actually performing the work which previously required 20,407 gravity cells.

The cost of these chloride cells was about $8,500. Allowing 15% for auxiliary apparatus necessary to charging brings this figure up to $9,775. Bought in large numbers, gravity cells can be obtained for fifty cents a piece. At this figure the total cost of the displaced cells is $10,203.50.

When it comes to maintenance the figures are decidedly in favor of the storage battery, Professor F. B. Crocker† has estimated that the cost of one horse-power hour from gravity cells was 56 cents. This can perhaps be reduced to 50 cents; but taking into account the efficiency of the gravity cell which may be only about 33⅓% on account of local action, raises this figure to about $1.50.

One horse-power hour delivered from a storage battery, calling

* The Storage Battery in Telegraph Work, by Maurice Barnett. *Electrical World*, July 13, 1896, and *American Electrician*, March, 1897.

† Transactions of the American Institute of Electrical Engineers, Vol. 5, p. 277.

the efficiency 75%, would require one kilowatt hour input. The maximum rate charged by the New York Edison Co. for this amount of energy is 20 cents. If charged from own lighting circuit the cost is very low, being less than one cent per horse-power hour output of battery if the following figures are taken: Coal $2.50 per ton, 4 pounds of coal per indicated horse-power of engine per hour, 80% efficiency of transformation of mechanical into electrical energy and 75% efficiency of cells. This figure can hardly be raised to two cents per horse-power hour even under very unfavorable conditions and under good conditions may be appreciably lowered. The maintenance of storage battery is also claimed to be less than that of gravity cells.

Aside from monetary questions the storage battery has the following additional advantages:

1. For a given output it has only ⅙ to $\frac{1}{10}$ the cubic volume of gravity battery.

2. Any number of circuits can be worked in parallel from a battery of sufficient capacity.

3. The internal resistance is a constant, this is, however, offset by the variation in the E. M. F., as the cells discharge.

4. The attention required is much less and there is no trouble from excessive evaporation and creeping of salts, although when of large output there is trouble from acid spray.

Unless a lighting plant is already installed in the building or electric current is available from a central station, dynamos and dynamotors are out of the question except when the primary cells employed would number thousands. But in these cases their first cost is even less than an equivalent output of storage batteries while their maintenance is fully as low. In small units, however, the efficiency of dynamos is not over 65% and of dynamotors about 42%, especially if not fully loaded. The cost, therefore, of one horse-power hour output may be greater than in the case of a storage battery of 75% efficiency. The armature resistance is only a small fraction of an ohm and of the same order as the internal resistance of the storage battery of the same voltage, so just as many lines can be fed in parallel. The Western Union plant in New York consists of 15 dynamos which displaced about 30,000 gravity cells. This to equal the cost of the cells would allow $15,000 or an average of $1,000 per dynamo unit. In Albany 7,000 cells were discarded and 9 small dynamos driven by a 7½

horse-power motor took their place. This could again not have equalled the cost of the cells, viz., $3,500. A ⅙ dynamotor having an output of $\frac{1}{12}$ horse-power will displace about 800 gravity cells, the ratio of the volumes being about as one is to fifteen and the cost as one is to ten.

There are absolutely no drawbacks to dynamos or dynamotors as the voltage and internal resistance remain constant and there is, of course, no creeping of salts or spraying of acid.

For further information the reader is referred to the following books and articles: The Voltaic Cell, by Park Benjamin, New York, 1893; Primary Batteries, by H. S. Carhart, Boston, 1891; Secondary Batteries; by J. T. Niblett, London, 1891; Electric Lighting, by F. B. Crocker, New York, 1896; Vol. I., Chapter XVIII., on Dynamos, and Chapter XX., on Accumulators; Vol. II., Chapter V., Treating of Dynamotors; The Manufacture of Chloride Accumulators, *Electrical Engineer*, December 19, 1894; The Electric Storage Battery Co., Its Factory and its Installations, *Electrical Engineer*, April 28, 1898.

ABSTRACTS.

INDEX TO MINERALOGICAL ARTICLES WITH NOTES.

By

A. J. MOSES AND L. McI. LUQUER.

PRINCIPAL ABBREVIATIONS USED.

Amer. Jour. Sci.—The American Journal of Science (New Haven).
Ber. Ak. Berlin.—Monatsberichte der k. preuss. Akad. der Wissen. zu Berlin.
Ber. Ak. München.—Sitzungsberichte der k. bayerischen Akad. der Wissen. zu München.
Ber. Ak. Wien.—Sitzungsberichte der k Akad. der Wissen. zu Wien.
Ber. Sächs Ges. Leipzig.—Berichte der k. Sächs. Gessell-der Wiss., Leipzig.
Bull. Soc. Min.—Bulletin de la Société Française de Mineralogie (Paris).
C. R.—Comptes Rendus des Séances de l' Academie des Sciences.
G. För. Förh.—Geologiska Föreningens i Stockholm Förhandliger.
Min. Mag.—The Mineralogical Magazine (London).
Minn. Mitth.—Tschermak's Mineralogische und Petrographische Mittheilungen.
Neues Jahrb. Min.—Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie (Stuttgart).
Wied. Ann.—Annalen der Physik und Chemie.
Zeit. f. Kryst.—Zeitschrift für Krystallographie und Mineralogie (Leipzig).

GENERAL CRYSTALLOGRAPHY.

Zur Definiton des Begriffes Krystall.—J. W. Retgers.—*Neues Jahrb. Min.*, 1895, II., 167; L. Wulff.—*Neues Jahrb. Min.*, 1896, II., 123.

Das Grundgesetz der Krystallographie.—E. v. Federow.—*Verh. d. russ. k. Min. Ges.*, 1895, X., 81; *Neues Jahrb. Min.*, 1896, II., 2 Ref.

An attempt to formulate fundamental laws of physical and geometric crystallography.

Use of the Globe in crystallography.—J. Y. Buchanan.—*Phil. Mag.*, 1895, XL., 153.

Method for making spherical projections and calculations directly on a black globe.

STRUCTURE.

Theorie der Krystallstructur.—E. v. Federow.—*Zeit. f. Kryst.*, XXV., 113, 224; A. Fock.—*Ibid.*, 565.

Die Structur der hemimorph-hemiëdrischen bezw. tetardoedrischen drehenden Krystalle.—L. Sohncke.—*Zeit. f. Kryst.*, XXV., 529.

Ueber das compacteste regelmässige Kugelsystem.—E. v. Federow.—*Zeit. f. Kryst.*, XXVIII., 232.

Verknüpfung der Krystallpartikel.—V. Goldschmidt.—*Zeit. f. Kryst.*, XXIX., 38, 361.

Entwicklung der Krystallformen.—V. Goldschmidt.—*Zeit. f. Kryst.*, XXVIII., 1, 414.

Schichtengebau der Krystalle.—A. Pelikan.—*Min. Mitth.*, XVI., 1.

Homogeneous Structures and the Symmetrical Partitioning of them, with application to crystals.—Wm. Barlow.—*Min. Mag.*, XI., 119, 1896; also, *Zeit. f. Kryst.*, XXVIII., 449.

General statement of the "kind of repetition in space which constitutes homogeneity of structure." Total number of types of arrangement 230, these all falling into the 32 classes of crystal symmetry. Method given for constructing illustrating models.

Geometrische Untersuchung über eine Mechanische Ursache der Homogenität der Structur und der Symmetrie.—W. Barlow.—*Zeit. f. Kryst.*, XXIX., 433.

Homogenität.—C. Viola.—*Zeit. f. Kryst.*, XXVIII., 452; XXIX., 1, 234.

Homogeneous space division.—Lord Kelvin.—*Proc. Roy. Soc. Lond.*, LV., 1. *Nature*, XLIX., 475.

SYMMETRY.

Die Symmetrieebene als Grundelement der Symmetrie.—G. Wulff.—*Zeit. f. Kryst*, XXVII., 556.

Ein Wort über das Symmetriecentrum.—F. Becke.—*Zeit. f. Kryst.*, XXV., 73.

Prefers symmetry with reference to center and axes, to symmetry with reference to planes and axes. Deduces 32 groups on this basis.

Uber die Symmetrie der Krystalle und Anwendung der Quaternionrechnung.—C. Viola.—*Neues Jahrb. Min.*, Beil. Bd., X., 495, 1895–6.

Beitrag zur Syngonielehre.—E. v. Federow.—*Zeit. f. Kryst.*, XXVIII., 36–68, 468–482.

Division of crystals according to syngony or angle similarity instead of system.

Elementare Darstellung der 32 Krystallklassen.—C. Viola.—*Zeit. f. Kryst.*, XXVII., 1.

Starting with nonsymmetrical figure, obtains higher grades by one, two or three reflections. Introduces new symbols S with two indices, the second giving grade of symmetry of principal axis, the first the grade of the other axes. For example S_{84}.

Beweis der Rationalität einer dreizahligen Symmetrieaxe.—C. Viola.—*Zeit. f. Kryst.*, XXVII., 399; V. de Souza-Brandão, *Ibid.*, 545.

Ueber die Beziehungen der regulären und halbregulären Polyëder der Geometrie zu krystallonomisch möglichen Gestalten.—F. Herrmann.—*Zeit. f. Kryst.*, XXVII., 285.

The relation between morphological and optical symmetry in crystals. W. Barlow.—*Report British Assn.*, 1895, 617.

CURVED AND VICINAL PLANES, ETC.

Ueber krumme Flächen (Ubergangsflächen).—V. Goldschmidt.—*Zeit. f. Kryst.*, XXVI., 1.

Ueber die Natur und die Entstehung der Vicinalflächen der Krystalle. —A. Karnojitzky.—*Verh. d. russ. k. min. Gesell. St. Petersburg*, XXIII., 65–228; *Neues Jahrb. Min.*, 1898, I., 3 Ref.

Concludes from study of Beryl and apatite that the vicinal angles of the faces in zone [$2\bar{1}\,\bar{1}$] can be deduced one from the other by multiplying a fundamental angle by $0, \frac{1}{2}, 1, \frac{3}{2}$, etc.; that is they should not be regarded as belonging to same individual with complicated indices but to a series of individuals twinned after slight rotation.

Anomalien in der Grösse der Krystallwinkel und die Polyëdrie der Flächen als Folge der agglomeration der Krystalle.—M. Jerofeev.—*Verh. d. russ. k. min. Ges.*, XXX., 345; *Neues Jahrb. Min.*, 1896, I., 382, Ref. These anomalies show a constant variation.

Wiederkehr gleicher Flächenwinkel im regulären Krystallsysteme.—A. Schmidt.—*Zeit. f. Kryst.*, XXV., 477.

Ueber Zonenstructur der Krystalle in Erstarrungsgesteinen.—F. Becke.—*Min. Mitth.*, XVII., 97.

Measurement and Calculation.

Die Einführung des geometrischen Rechnens in die geometrische Krystallographie.—C. Viola.—*Neues Jahrb. Min.*, Beil. Bd., X., 167, 1895–6.

Ueber geometrische Ableitung in der Krystallographie.—C. Viola.—*Ziet. f. Kryst.*, XXVI., 113.

Reciproke Krystallformen und reciproke Krystallprojectionen. Dissertation of M. Schwarzmann, Giessen, 1897; *Neues Jahrb. Min.*, 1897, II., 434, Ref.

Hilfsmittel um die Ausrechnung der Mallard'schen Formel zu ersparen.—M. Schwarzmann.—*Neues Jahrb. Min.*, 1896, I., 52.

Crystal Measurement by Means of Angular Coördinates and the Use of the Goniometer with Two Circles.—C. Palache.—*Am. Jour. Sci.*, IV., Vol. II., 279, 1896.

The system is equivalent to the determination of the latitude and longitude of a place by reference to the equator and prime meridian. Any great circle of the sphere of projection may be taken as the equator and any great circle at right angles to the equator may be taken as the first or prime meridian. When possible the crystal is so mounted that the prism zone is at right angles to the equator (the circle with horizontal axis), or, what is the same thing, the plane at right angles to the prism zone is taken as the *pole*. The crystal, once adjusted, has each face brought to reflection by movements of the horizontal and vertical circles, and the angles φ and ρ observed. The angular coördinates of the faces are independent of any other face, and give an absolute picture of the crystal as it is, free from the approximations and averages introduced when measurement is by zones. The interfacial angles can also be obtained if desired.

The discussion of the results can proceed directly, but the graphical method, based on gnomonic projection, is more convenient; as it gives a direct picture of the crystal showing its degree of symmetry and the relation of its faces. When the projection is carried out with care the results obtained for axial elements, by measurement taken from it, are very accurate; often agreeing with calculated results to the second or third decimal place.

This method of taking measurements enables all good faces of the crystal

to be employed in the final determination of the crystallographic elements, and the use of spherical trigonometry is dispensed with, thus keeping the whole computation before the eye and making easy the detection of errors.

The gnomonic projection serves further as a basis for the construction of other projections. The apparatus is described in detail with cuts.

The foregoing principles have been applied in a *contact goniometer*, described later. A concise description is also given of Goldschmidt's *projection goniometer*.—L. McI. L.

Das zweikreisige Goniometer (Modell 1896) und seine Justirung.—V. Goldschmidt.—*Zeit. f. Kryst.*, XXIX., 333.

Ein einfaches Theodolitgoniometer und seine verwendung zu stauroskopischen Bestimmung.—F. Stöber.—*Zeit. f. Kryst.*, XXIX., 25.

A vertical circle which can be attached to Fuess horizontal goniometer converting it into a two circle goniometer.

Universal (Theodolit) Goniometer, of E. v. Federow.—*Neues Jahrb. Min.*, Beil. Bd., X., 192.

Universal goniometer.—Czapski.—*Neues Jahrb. Min.*, 1897, I., 78.

Ein Projectionsgoniometer.—V. Goldschmidt.—*Zeit. f. Kryst.*, XXV., 538. By which the gnomonic projection of the crystal is obtained without reading of angles or calculation and so accurately that the elements may be determined therefrom to the second decimal. The instrument is so devised that, after the proper reflection has been obtained from any face, the crystal can be removed and a pointed rod (by the construction of the instrument always normal to the face observed) lowered and thus made to record directly the projection of the face normal on a piece of paper resting on the lower horizontal circle. Angular measurements may also be taken with the instrument.—L. McI. L.

Universalinstrument für Krystallographie.—C. Viola.—*Zeit. f. Kryst.*, XXVIII., 165.

Combination of two circle goniometer, with polarizing microscope whereby the position of the optic axes is determined directly.

Ueber Grobgoniometer.—V. Goldschmidt.—*Zeit. f. Kryst.*, XXIX., 589.

Forms of Simple goniometers for measurement of coarse, dull crystals.

Anlegegoniometer mit zwei Kreisen.—V. Goldschmidt.—*Zeit. f. Kryst.*, XXV., 321. The instrument consists of a horizontal circle rotating about a vertical axis. The vertical circle is fixed, but upon it moves a guide piece carrying a radially directed arm, at the end of which is a little application plate. The movements necessary to make this application plate parallel to the different crystal faces yield the constants of measurement accurate to within ½°.

Index of Refraction.

Method of Determination of Index of Refraction in thin Mineral Sections.—C. Viola.—*Min. Mitth.*, XVI., 150. Method based on that employed by Becke and Michel Lévy. The difference between the indices of two minerals in contact is directly proportional to the square of the opening in the iris-diaphragm necessary to show the "bright line" most distinctly. If D = radius of opening of iris-diaphragm, n_2 and n_1

= the two indices of the minerals in contact and λ = a constant; then we have:

$$n_2 - n_1 = \lambda D^2.$$

The constant λ can be determined from two minerals with known indices, one of which is to be used in the subsequent determination. Accurate results have been obtained to the third decimal place.—L. McI. L.

Indices of Refraction of Rock Making Minerals, Determination of.—F. Wallerant.—*Bull. Soc. Min.*, XX., 234, 1897. The indices are obtained by the principle of total reflection, and a microscope with special accessory apparatus must be used for the determination. A stand, fitting on the microscope stage, is provided with a plate, which can have definite rotation on its horizontal axis. This plate carries a little glass prism (index of refraction 1.89), to the lower surface of which can be attached the crystal section whose indices are to be determined. If a single crystal in a rock section is to be examined, an iris-diaphragm is used to isolate the rest of the section.—L. McI. L.

Note sur la détermination de l'indice de réfraction de prismes à grands angles réfracteurs.—F. Stöber.—*Bull. Ak. Roy. de Belg.*, XXX., 520; *Neues Jahrb. Min.*, 1897, II., 248, Ref. A modification of Brögger-Ramsay Method (see *Zeit. f. Kryst.*, XII., 209 and XXVIII., 109).

Ueber den Brechungsexponenten einiger pigmentirter Mineralien.—C. Hlawatsch.—*Zeit. f. Kryst.*, XXVII., 605.

Investigates quartz, sillimanite and fluorite, and finds that coloring matter exerts a measurable influence on the indices of refraction.

Three Particular Cases of Refraction in Crystals.—J. Verschaffelt.—*Bull. Soc. Min.*, XIX., 40, 1896.

1° Single refraction in double-refracting crystals.

2° Directions following which a ray of light can pass from an isotropic medium into a crystalline medium without deviation.

3° Directions following which a plane wave of light can pass from an isotropic medium into a crystalline medium, without losing its normal velocity.

Mathematical discussion with verification experiments.—L. McI. L.

Die Refractionsconstanten krystallisirter Salze.—W. J. Pope.—*Zeit. f. Kryst.*, XXVIII., 113.

Sur la réfringence des aureoles polychroiques.—A. Michel-Lévy.—*C. R.*, CXX., 278; *Neues Jahrb. Min.*, 1896, I., 202, Ref.

Ueber die Berechnung des variablen Werthes der Lichtbrechnung in beliebig orientirten Schnitten optische einaxiger Mineralien.—W. Salomon.—*Zeit. f. Kryst.*, XXVI., 178.

If ω and ϵ are known the value of ϵ' for any section can be calculated when angle α of plate normal with optic axis is known.

Axial Angle.

Ueber die Messung des Winkels der optischen Axen.—W. J. Pope.—*Zeit. f. Kryst.*, XXVI., 589.

To obtain the angle between a visible optic axis and the plate normal, without previous determination of normal, the adjusted plate in air is in-

stalled at the axial figure and then dipped in a parallel-walled glass vessel containing a strongly refracting liquid, and again installed at the axial figure. The difference of the readings is $\alpha - \theta$ in which α and θ are the angles of the plate normal with the optic axis in air and in the liquid. Denoting index of liquid by μ there is deduced

$$\cot \alpha = \cot (\alpha - \theta) - \frac{1}{\mu \sin (\alpha - \theta)}$$

Methode Zur Bestimmung der Lage der optischen Axen in Dünnschliffen. —C. Viola.—*Min. Mitth.*, XV., 481.

Messung des Winkels der optischen Axen in Mikroskop.—H. Lenk.—*Zeit. f. Kryst.*, XXV., 379; also described *Neues Jahrb. Min.*, Beil. Bd., X., 429.

A thin glass with micrometer scale is placed in the back focal plane of the objective.

Extinction Direction.

Sur une méthode simple pour chercher la variation de l'angle d'extinction dans les différentes faces d'une même zone.—G. Cesaro.—*Mem. ac. roy. sc. Belg.*, 1894, LIV., 26; abst. *Zeit. f. Kryst.*, XXVIII., 181.

If the position of the zone axis with respect to the optic axis is given, assume a plane at a unit's distance from the center of the crystal and normal to the zone axis. Let I be the center of the crystal and C the point of intersection of the normal from I to the plane. The optic axes through I cut the plane in A and B.. From C draw CO normal to line AB. Denote OA by a, OB by b, OC by c, then, if the angle between extinction direction and zone axis be $2x$,

$$\tan 2x = \frac{(a + b) \sin \beta + 2c \cos \beta}{1 - (a \sin \beta + c \cos \beta)(b \sin \beta + c \cos \beta)}$$

in which β is the angle between the face concerned and the plane ICO. For application reference is made to the article.

Circularly Polarizing Crystals.

Ueber optisches Drehungsvermögen.—W. J. Pope.—*Zeit. f. Kryst.*, XXVII., 406.

Divides crystals in which rotation of vibration plane takes place, both in amorphous and crystalline condition, into: (*a*) Those in which in solid condition the rotation is due to pseudo symmetry (complex lamellar structure); (*b*) Those in which the rotation is a specific property of the crystallized substance.

Describes a new member of each (*a*) $C_{10}H_{14}O_6$; (*b*) $C_9H_{13}O_2COOH$.

Die Lichtbewegung in zweiaxigen activen Krystallen.—O. Weder.—*Neues Jahrb. Min.*, Beil. Bd., XI., 1.

Ueber die Krystallformen regulärer und optisch einaxiger Substanzen, deren Lösungen ein optisches Drehungsvermögen besitzen.—H. Traube. —*Neues Jahrb. Min.*, Beil. Bd., IX.

Obtains rotation of plane of vibration from isometric crystals of Coniine Alum $C_8H_{18}N\,Al\,(SO_4)_2 . 12H_2O$ and Laurineen Camphor $C_{10}H_{16}O$, the solutions of which are also optically active.

Ueber das Verhalten circular polarisirender Krystalle in gepulvertem Zustande.—H. Landolt.—*Ber. d. d. Chem. Gesell.*, XXIX., 2404; *Neues Jahrb. Min.*, 1898, I., 6, Ref.

Sodium chlorate crystals were finely powdered and suspended in mixture of absolute alcohol and carbon disulphide of the same refracting power. No diminution in power of rotation was observed, although *in solution* there was no rotation at all.

Beiträge zur Kenntniss der Krystallform optisch activer Substanzen.—L. Brugnatelli.—*Zeit. f. Kryst.*, XXVII., 78. Santonin and some of its derivatives.

Sur un nouveau corps à double pouvoir rotatoire.—G. Wyrouboff.—*Jour. de Phys.*, III., 451; abs. *Zeit. f. Kryst.*, XXVII., 440.

Strychnine sulphate and matico-camphor are left rotating in both solid and dissolved state, succinate of apocinchonins is right rotating in both conditions but the new substance, tartrate of rubidium, is left rotating in solid state and right rotating in solution, or if made from left tartaric acid these are reversed.

Der Beziehungen der im amorphen und krystallinischen Zustande auftretende Circularpolarisation zu der Symmetrie und Theilung homogener Strukturen, d. h. der Krystalle.—W. Barlow.—*Zeit. f. Kryst.*, XXVII., 468.

Ueber das optische Drehungsvermögen von Körpern im krystallinischen und in amorphen Zustande.—H. Traube.—*Neues Jahrb. Min.*, Beil. Bd., X., 789, 1895–6; XI., 623, 1896–7.

Certain isometric and uniaxial crystals which are optically active in solution, lack in themselves either circular polarization or if such is present it stands in no recognizable relation to the molecular rotation (due to the structure of the molecule). For instance: in Laurineen Camphor the specific molecular rotation (shown in solution) and the rotation in the crystal are about equal; in Matico Camphor they are respectively 0.315 and —1.877, that is as 1:6 *and in opposite directions*; in tartrate of rubidium they are 0.69 and 10.24, or as 1:15.

Dé la double réfraction elliptique et de la tétra-réfringence der quartz dans le voisinage de l'axe.—G. Quesneville.—*C. R.*, 1895, XXI., 525.

Absorption and Pleochroism.

Absorption de la lumière par les cristaux.—E. Carvalho.—*Ann. de chim. et de phys.*, VII., 58; abs. *Zeit. f. Kryst.*, XXIX., 686.

Absorption of light in isotropic and crystalline media.—M. G. Moreau.—*C. R.*, 1894, CXIX., 327; 1895, CXX., 258, 602.

Etude experimentale sur l'absorption de la lumière par les cristaux.—C. Camichel.—*Ann. de chim. et de phys.*, 1895, V., 433; abs. in *Zeit. f. Kryst.*, XXVII., 643.

By special spectrophotometer investigates and confirms the theory that the absorption constants can be referred to the "absorption ellipsoid," but finds that the axes of absorption ellipsoid and elasticity ellipsoid do not in general coincide in direction.

Recherches sur l'absorption et la dispersion de la lumière par les milieux doués de pouvoir rotatoire.—A. Cotton.—*Jour. de Phys.*, V., 237,

290; abs. *Zeit. f. Kryst.*, XXIX., 690. In colored solutions of some tartrates a light ray previously made right-handed by a quarter undulation mica plate is differently absorbed in the solution than one made left-handed. This he calls circular dichroism.

Ueber den Dichroismus von Kalkspath, Quarz und Turmalin für ultrarothe Strahlen.—E. Merritt.—*Wied. Ann.*, LV., 49.

Sur la théorie Electromagnetique de l'absorption de la lumière dans les Cristaux.—R. Brunhes.—*C. R.*, 1895, CXX., 1041.

Die Absorption des Lichtes in einigen pleochroitischen Krystallen.—Joh. Ehlers.—*Neues Jahrb. Min.*, Beil. Bd., XI., 259, 1896–7.

Luminescence.

Ueber Luminiscenz.—E. Wiedemann und G. C. Schmidt.—*Wied. Ann.*, LIV., 604; *Neues Jahrb. Min.*, 1897, I., 7 Ref.

Luminescence, or light emergence without corresponding increase of temperature, Wiedemann subdivides according to producing cause into:

1. Light (Photoluminescence) including fluorescence and phosphorescence.
2. Electric charges (Electroluminescence).
3. Kathode rays (Kathodoluminescence).
4. Breaking or rubbing (Triboluminescence).
5. Heat (Thermoluminiscence).
6. Chemical processes (Chemiluminescence).

Steinsalz und Fluorit, ihre Farbe, Fluorescenz und Phosphorescenz.—F. Kreutz.—*Anzeiger d. ak. d. Wissen.; Neues Jahrb. Min.*, 1897, I., 7, Ref.

Ueber Luminescenz.—W. Arnold.—*Zeit. f. Kryst.*, XXVII., 92.

Author investigates a series of Benzyl groups with respect to Kathodo-, Thermo- and Triboluminescence.

Polarisirte Fluorescenz; ein Beitrag zur kinetischen Theorie der festen Körper.—L. Sohncke.—*Ber. Ak. München*, XXVI.; *Wied. Ann.*, LVIII., 417; *Neues Jahrb. Min.*, 1898, I., 4, Ref.

Developes fluorescence in many crystals by action of sunlight passed through a violet ray filter and made slightly conical by a lens of quartz. Often this ray was then polarized by a nicol. If capable of fluorescence singly refracting substances develope a non-polarized fluorescence, but doubly refracting develope a polarized fluorescence.

Ein bemerkenswerther Fall von Phosphorescenz.—W. J. Pope.—*Zeit. f. Kryst.*, XXV., 567.

Ueber Lichterscheinungen während der Krystallization.—E. Bandrowski.—*Zeit. f. phys. Chemie*, XV., 323; XVII., 234; *Neues Jahrb. Min.*, 1896, II., 4, Ref., 1897, I, 226, Ref. Apparently is due to a chemical process, not to change from amorphous to crystalline structures as assumed by Rose.

X-Rays.

Verhalten der Mineralien zu den Röntgenschen X-Strahlen.—C. Doelter.—*Neues Jahrb. Min.*, 1896, II., 87; 1897, II., 255.

Anwendung der Röntgenschen X-Strahlen auf die Unterscheidung von

Diamant, Bergkrystall und Strass.—C. Doelter.—*Neues Jahrb. Min.*, 1896, I., 211.

Obtains relative penetrability of some seventy minerals, but does not find any very definite relation between density and penetrability, or chemical composition and penetrability, or molecular weight or volume and penetrability.

As to effect of crystalline direction in tourmaline none could be shown. In quartz the penetrability was apparently slightly greater parallel $\dot{c}$, in apatite the opposite. In fact, all differences were very small and subject to doubt.

A use is suggested in distinguishing precious stones.

Diamond (transparent) easily distinguished from topaz, quartz and strass (opaque). Röntgen's law, that the transparency is inverse to the specific gravity, must be modified for minerals below 5.

Roentgen Rays, Relative Opaqueness of some Minerals to.—W. L. Goodwin.—*Nature*, April 30, 1896; abs. in *Bull. Soc. Min.*, XIX., 130, 1896.

Phosphorescence of Minerals under X-Rays.—J. E. Burbank.—*Am. Jour. Sci.*, IV., Vol. V., 53, 1898.

Tests made on many minerals of which two-thirds phosphoresced to greater or less degree. Mineral group containing Ca most susceptible, especially fluorite and calcite. Feldspar group and other silicates showed phosphorescence, but in general minerals containing ores of the metals were non-susceptible. Effects of heating in addition to action of X-Rays also noted.—L. McI. L.

Optical Examination of Feldspars.

Determination of the Feldspars.—N. H. Winchell.—*Am. Geol.*, XXI., 12, 1898.

Method for Practical Determination of the Plagioclases in a Particular Case.—L. Bertrand.—*Bull. Soc. Min.*, XX., 219, 1897.

A mechanical device (illustrated by cuts) for obtaining quickly the results given by using "épure" XII. in Michel Lévy's *Etude sur la determination des feldspaths*.

Universal methode und Feldspath Studien.—E. von Federow.—*Zeit. f. Kryst.*, XXVI., 225; XXVII., 337; XXIX., 604; XXV., 351.

Review of this Method by Fred. Wallerant.—*Bull. Soc. Min.*, XIX., 356, 1896.

Calculation of the Optical Constants of a Mixture of Isomorphous Substances. Application to the Feldspars.—Fred. Wallerant.—*Bull. Soc. Min.*, XIX., 169, 1896. Mathematical Discussion.

A use of Zone Intersections in Determination of Feldspars.—L. Duparc. & F. Pearce.—*Arch. des Sc. phys. et nat.*, III., 155, 1897; abs. *Zeit. f. Kryst.*, XXIX., 696.

Proof of correctness of Tschermak's law for Plagioclase, and new method for Orientation and Determination of the Feldspars in thin Sections.—A. Michel Lévy.—*C. R.*, 1895, CXXI., 74; abs. *Zeit. f. Kryst.*, XXVII., 539.

MICROSCOPES AND ATTACHMENTS.

Ueber Neuconstructionen von Instrumenten für krystallographische und petrographische Untersuchungen.—C. Leiss.—*Neues Jahrb. Min.*, Beil. Bd., X., 179, 412, 1895.

v. Federow universal stage; a universal rotation apparatus of Klein especially for the investigation of precious stones; an attachment for determination of the axial angle by the principle of Adams; the Gauss mirror attachment by which to recognize when a crystal face is normal to the microscope axis, or in connection with rotation apparatus to form a microgoniometer; simpler forms of microscopes with simultaneously rotating nicols; Amman's compensator eye-piece; vertical illuminator consisting of a short collar (containing total reflecting prism) to be inserted above objective.

Mittheilungen aus der R. Fuess'chen Werkstätte.—C. Leiss.—*Neues Jahrb. Min.*, 1896, II, 253; 1897, I., 74; II., 86–95.

Microscope with exceptionally large field, dichroscopic eye-piece giving direct comparison; latest form v. Federow stage, etc.

Ueber Universaldrehapparate.—C. Klein.—*Ber. Ak. Berlin*, 1895, 91, 1151; abs. *Zeit. f. Kryst.*, XXIX., 401.

Simple Instrument for Inclining a Preparation in the Microscope.—T. A. Jaggar, Jr.—*Am. Jour. Sci.*, IV., Vol. III., 129, 1897.

The instrument is very simple in construction, motion about two axes at right angles to each other being obtained by a universal ball and socket joint. The use of such an apparatus may be necessary in petrographical work for the orientation of feldspar twins for determination by Michel-Lévy's method, the obtaining of well-defined interference figures from obliquely cut sections, etc. The limit for tipping was about 44° as found by the writer. To allow for the tipping of the section it may be necessary to have the condenser mounted in a steeply conical cell, and a special long-focus conoscopic combination of objective and condenser is recommended for interference figures in sections requiring high magnification. L. McI. L.

Zur Systembestimmung mikroskopischer Krystalle.—J. L. C. Schroeder van der Kolk.—*Zeit. f. Wiss. Mikros.*, XII., 188; *Neues Jahrb. Min.*, 1897, I., 224, Ref.

Uses glass hemisphere larger than the opening in the microscope stage and plane side up. The solution is crystallized on a thin cover glass, then united by oil or balsam to the plane side where it can be turned easily as desired.

Ueber den Zwillingscompensator.—K. v. Chrustschoff.—*Verh. d. Russ. K. Min. Ges.*, St. Petersburg (2) XXXIV; *Neues Jahrb. Min.*, 1897, II., 246 Ref.

Two Babinet compensators turned 180° on each other, one covering upper half of field the other the lower half. The interposition of a doubly refracting substance sends the dark band in one to left, in other to right, and the distance apart is easier to measure than the distance from cross hair to stripe in single Babinet.

Eine empfindliche Quarzdoppelplatte.—F. Stöber.—*Zeit. f. Kryst.*, XXIX., 22.

Instead of Bertrand's eye piece of quadrants of alternately right-handed and left-handed quartz, uses two right triangles in contact at hypothenuse and forming a square of which two adjacent sides are parallel to $\dot{c}$, that is in the two halves the directions of $\dot{c}$ are at right angles.

Eine einfache Glimmerdoppelplatte zu Stauroskopischen Bestimmungen. —H. Traube.—*Neues Jahrb. Min.*, 1898, I., 251.

Consists of two quarter undulation rectangular mica plates side by side, with planes of optic axes at seven degrees to each other.

Double Refraction, Determination of, in thin sections.—Note by F. Wallerant, *Bull. Soc. Min.*, XX., 172, 1897.

By means of small mirrors suitably arranged, light is made to pass twice through the thin section, hence *doubling* its apparent thickness. In this way a sufficiently marked interference color is obtained to be measured by a Michel Lévy comparator.

Sundries Optical.

Polarized Light, Recent Progress in Optics.—W. Le Conte Stevens.—*Amer. Jour. Sci.*, III., Vol. L., 382, 1895.

Calcite rapidly diminishes in power of transmission for waves of short period. Application of polarized light to the investigation of internal stress in transparent media.

The apparent causes of the anomalous double refraction of crystals.—A. Bensaude.—*Lisbon National Press*, 1896; *Neues Jahrb. Min.*, 1897, II., 249, Ref. Attributes anomalies in garnet, alum and analcite, to unequally distributed density (structural irregularity) producing strains. Assumes that directions of minimum growth in anomalous crystals show lesser density.

Beitrag zur theoretischen Erklarung der Interferenzerscheinungen, welche Platten aus Zwillingskrystallen in convergenten polarisirten Lichte zeigen.—B. Hecht.—*Neues Jahrb. Min.*, Beil. Bd., XI., 318, 1896–7.

Verschiedene Grade von Durchsichtigkeit an einzelnen Chlornatrium krystall.—C. Ochsenius.—*Zeit. f. Kryst.*, XXVIII., 305.

Evaporation of salt solution 35 days over a layer of coarsely powdered sandstone gave a number of loose hexahedra, which showed differences in transparency to the naked eye, in part opaque, in part transparent; the darker portion forming a sort of cross in direction of diagonals of a face.

Ueber Dispersion ultravioletter Strahlen.—H. Th. Simon.—*Inaug. Dissert., Berlin*; abs. *Wied. Ann.*, LIII., 542; *Zeit. f. Kryst.*, XXVII., 443.

Refraction and dispersion of ultraviolet rays in some crystalline substances.—G A. Borel.—*C. R.*, CXX., 1404, 1895; abs. *Zeit. f. Kryst.*, XXVIII., 103.

Zur Dispersion der ultrarothen Strahlen in Fluorit.—H. Rubens.—*Wied. Ann.*, LI., 381, 1894; F. Paschen.—*Ibid.*, LIII., 301; abs. *Zeit. f. Kryst.*, XXVII., 440, 442.

Ueber die Wellenlängenscala des ultrarothen Flussspath Spectrums.—F. Paschen.—*Wied. Ann.*, LVI., 762; abs. *Zeit. f. Kryst.*, XXVIII., 628.

Vervollkommnung des Dichroskopes.—A. Cathrein.—*Zeit. f. Inst.*, 1896, 226; *Neues Jahrb. Min.*, 1898, I., 7, Ref.

Makes adjustable so that the two rectangular images may be always brought side by side forming a square.

Die neueren Projectionsapparate von R. Fuess.—C. Leiss.—*Neues Jahrb. Min.*, Beil. Bd., XI., 46, 1896–97.

Universalapparat für refractometrische und spectrometrische Untersuchungen.—C. Pulfrich.—*Zeit. f. Inst.*, XV., 389; abs. *Zeit. f. Kryst.*, XXIX., 400.

Ein neues Spectralphotometer.—A. König.—*Wied. Ann.*, LIII., 785; abs. *Zeit. f. Kryst.*, XXVII., 439.

THERMAL.

Bestimmung der Ausdehnung durch die Wärme und des elektrischen Leitungsvermögens des Eisenglanzes.—H. Bäckström.—*Öfv. a. K. Vetenskaps-Ak. Förh.*, 1894, No. 10, 545; *Neues Jahrb. Min.*, 1897, I., 237, Ref. Parallelopiped cut from hematite, of near Kragerö, Norway, the edges being c, a and the intermediate axis normal to both. Used Fizeau's method with tripod of platinum-iridium. The expansion coefficients in directions parallel and normal c were almost equal.

Spectres calorifique.—E. Carvalho.—*Ann. de chimie et de phys.*, 1895, IV., 5; abs. *Zeit. f. Kryst.*, XXVII., 641.

Versuch einer Theorie der Thermodynamik der Krystalle.—E. v. Federow.—*Zeit. f. Kryst.*, XXVIII., 483.

Ueber Schmelzpunktsbestimmungen bei Glühhitze.—V. Meyer; W. Riddle.—*Ber. d. Deutsch. chem. Ges.*, XXVII., 766, 3129; *Neues Jahrb. Min.*, 1896, I., 6, Ref.; II., 6, Ref.

Uber Beziehung zwischen dem Schmelzpunkt von Mineralien, ihrer Zonenstructur und ausscheidungsfolge in Ergussgesteinen.—R. Brauns.—*Min. Mitth.*, XVII., 485.

Der Schmelzpunkt von Gemischen isomorpher Substanzen.—F. W. Küster.—*Zeit. f. Phy. Chem.*, XV., 86; *Neues Jahrb. Min.*, 1896, I., 387, Ref.

MAGNETIC.

Recherches sur l'aimantation de la Magnétite cristallisée.—P. Weiss.—*Bull. Soc. Min.*, XX., 137, 1897.

The author determines the curves of magnetic intensity by a new method; and shows that these curves exhibit very different characteristics, relative to the directions of the quaternary, ternary and binary axes of the cubic system.

An hypothesis of "net" structure is sufficient to account for these facts.

The magnetic properties accord very well with the cubic symmetry; but, contrary to what would have been supposed from the optical properties of cubic crystals, the magnetic intensity of magnetite varies with the direction relative to the crystallographic axes.—L. McI. L.

Aimantation non isotrope de la Magnétite cristallisée.—P. Weiss.—*C. R.*, CXXII., 1405; *Neues Jahrb. Min.*, 1898, I., 435, Ref.

Prisms cut parallel to ternary axis are most strongly magnetized, those parallel to a binary axis only a little more feebly and those parallel to a quaternary axis markedly more weakly.

Magnetic behavior of Pyrrhotite.—A. Abt.—Abs., *Zeit. f. Kryst.*, XXVII., 100.

ELECTRICAL.

Ueber normale und anormale Dispersion elektrischer Wellen.—L. Grätz u. L. Fomm.—*Wied. Ann.*, LIV., 626; abs. *Zeit. f. Kryst.*, XXIII., 627. Just as indices of refraction vary with wave-length, so the dielectric constants depend upon the wave-length of the electric motion. But as these constants are commonly much larger than the squares of indices of refraction for waves of infinite length, it is to be inferred that these waves undergo absorption and thereby anomalous dispersion. If constants decrease with increased wave-length the dispersion is normal, but if the opposite abnormal.

Droppelbrechung Elektrischer Strahlen.—K. Mack.—*Wied. Ann.*, LIV., 342; LVI., 717; A. Righi—*Ibid.*, LV., 389; P. Lebedew—*Ibid.*, LVI., 1; W. v. Bezold—*Ibid.*, LIV., 752; abs., *Zeit. f. Kryst.*, XXVIII., 625–627.

The Polarization of Electric Rays by doubly refracting Crystals.—J. C. Bose, *Jour. Asiatic Soc.*, Bengal, LXIV., 291, 1895.

Wave-length of electric ray is very large when compared with that of visible light. By using electric radiations, of extremely short wave-length, satisfactory results were obtained from crystals of moderate size.

The electric ray is first polarized by wire grating, a similar grating acting as analyzer. The "receiver" is a modified form of "coherer" associated with a voltaic cell and galvanometer. The doubly refracting effect of the crystal is indicated by a throw of the galvanometer needle.

Apparatus and experiments are described. Minerals used: beryl, apatite, brucite, barite, microcline, halite and tourmaline. The experiments were conducted with relatively large and opaque crystals. In the case of toumaline absorption of the electric waves was noticed similar to that of light.

The crystals, experimented with, polarized the electric ray in the same manner as transparent crystals of the same mineral would polarize the light ray. L. McI. L.

Double refraction of the electrical waves in Gypsum.—A. Righi.—*Atti. della R. Acad. Luicei.*, 1895, II., 203; abs. *Zeit. f. Kryst.*, XXVIII., 185.

Ueber den Einfluss des Elektrostatischen Feldes auf das Optischer Verhalten piezo-Elektrischer Krystalle.—F. Pockels.—*Abh. d. k. Ges. d. Göttingen*, XXXIX, 1–204; abs. *Zeit. f. Kryst.*, XXVII., 444.

To determine whether the electro-optical phenomena are only the consequence of the deformation produced in the electric field or of a direct influence of the electric force on the light motions.

In sodium chlorate the influence is found to be 12 times that necessitated by the deformation.

In quartz the influence is greater than that produced by an equal mechanical deformation.

In seignnette salt the effect of the dielectric polarization parallel $\dot{c}$ is in the opposite sense to that of the accompanying deformation.

Piezo und Pyroelektricität, diëlektrische Influenz bei Krystallen ohne Symmetrie centrum. *Nach. v. d. k. Ges. Wiss Göttingen*, 343, 1894, abs. *Zeit. f. Kryst.*, XXVII., 437.

Die Bestimmung der Diëlektricitäts-constanten eines anisotropen Stoffes

nach einer beliebigen Richtung aus den Diëlektricitätsconstanten nach den Hauptrichtungen.—A. Lampa.—*Ber. Ak. Wein.*, CIV., 1179, abs. *Zeit. f. Kryst.*, XXIX., 399.

If $D_a D_b D_c$ are the principal constants the constant D_r for any direction is :

$$D_a \cos^2 (a.r) + D_b \cos^2 (b.r) + D_c \cos^2 (c.r)$$

Dispersion und Diëlektricitätsconstante.—F. Paschen.—*Wied. Ann.*, LIV., 668, abs. *Ziet. f. Kryst.*, XXVIII., 628. A mathematical discussion.

Ueber das Leitungsvermögen der Mineralien für Elektricität.—F. Beijerinck.—*Neues Jahrb. Min.*, Beil. Bd., XI., 403, 1896-7.

The tests were conducted with relatively simple apparatus, the object being to obtain comparative results. The method of Wartmann* was usually employed, a prism of known dimensions being introduced into a direct weak current, the strength modified by resistances and shunts, the deviation observed in a galvanometer and reduced to Siemens units.

Good contact was very essential, tough copper amalgam was preferred or sometimes bright sheet lead or simply graphite rubbed on with a lead pencil. Natural faces were cleaned with acid, caustic soda, water and alcohol, and sometimes even with hydrofluoric acid.

To study the effect of temperature on resistance the substance was heated in a small air bath made of double walls of asbestos and covered with copper, thus giving a very regular distribution of temperature without thermoelectric effects. An apparatus devised for resistance determination, in liquids was used and the Kohlrausch method.

Arbitrarily all substances, with a resistance of over ¼ megohm were classified as non-conductors.

To the conductors belong the metals, alloys, certain metalloids, most sulphides, tellurides, selenides, bismuthides, arsenides and antimonides, a part of the oxides and a few haloids, the latter only at higher temperature. (In general no division is made into metallic and electrolytic conductors.)

Oxides rarely conduct as well as sulphides. No oxide has as low resistance as galenite, ullmannite or niccolite, but the best oxide conductors pyrolusite, cassiterite, hematite, exceed in conductivity the metalloid sulphides such as molybdenite or bismuthinite.

To the non-conductors (isolators) belong most of the metalloids, certain sulphides, the greater portion of the oxides, almost all haloids, and all sulpho- and oxy-salts.

Some of the minerals occasionally described as conductors are so because of alteration coating, *e. g.*, realgar coated with hygroscopic mixture of orpiment, sulphuric acid and arsenic acid; pyrargyrite and proustite coated with dark mixture of argentite with stibnite or orpiment.

The effect of crystal structure was very slight in comparison to that of chemical structure. Anisotropic crystals showed slight differences in different directions.

If an absolute resistance of 2½ ohms is made the limit of conductivity, all monoclinic and triclinic crystals are non conductors, but there exists apparently no direct relation between the class of symmetry and the galvanic conductivity.

*Mem. de la Soc. d. hist. Nat. de Genève, XIII., 1853.

In general the modification originated at higher temperature or stable modification appears to be the better conductor. With enantiomorphic bodies at common temperature the less stable form is apparently the better conductor. This may be due to simpler structure at higher temperature.

Among the binary compounds the electronegative constituent of which is in the VII. series of the periodic system (H. Cl. Br. I) the conductivity increases with the atomic weight. Those binary compounds whose electronegative constituent belongs to the VI. series (O. S. Se. Te), however, behave exactly opposite.

On raising the temperature the conductivity increases with most of the hitherto studied binary compounds in a regular manner; a behavior exactly opposite to that of the metals. With the latter the conductivity decreases with rising temperature (apparently proportionately to the absolute temperature).

Of the non-conducters those of complicated structure apparently become, on heating, better conductors.

As examples of the author's method of applying the results to the determination of the place of minerals in classification take the following:

The resistance of allemontite AsSb is near those of its constituents, that of dyscrasite is not, the former therefore acts like an alloy, the latter like a compound.

The resistance of tetradymite of Cumberland and Banat, does not lie between that of bismuth and tellurium; it is, therefore, a compound, not an isomorphous mixture.

Acanthite, often considered to be distorted argentite, has a much higher conductivity; it is therefore distinct.

Sphalerite is a non conductor; wurtzite conducts poorly at ordinary temperatures, better at higher temperatures. Mallard stated that carefully heated sphalerite became doubly refracting from formation of wurtite. The author confirms this as follows: Of two cleavage plates of sphalerite one was carefully heated to redness in sulphur vapor, then both plates placed on zinc and with a pipette a little conc. $CuSO_4$ solution put on each; only on previously heated plate was copper deposited.

For similar reasons he thinks that the minerals of the bornite chalcopyrite group are sulphides not sulph-ferrates, etc.; that those of the spinel group are oxides, not aluminates, etc.; that cassiterite and polianite are oxides, not stannates, and that ilmenite is an isomorphic mixture. Interesting are comparisons like: conductivity pyrite good, marcasite poor, acanthite good, argentite poorer; metacinnabarite good, cinnabar nonconductor. Some of the accessory tests were very interesting, for instance the distinction of molybdenite and graphite is easy in thin sections by difference in conductivity. The absolute resistance of molybdenite is 2630 ohms, that of graphite $\frac{1}{265}$ to $\frac{1}{4518}$ ohms.

The test for purity: A thin gelatine layer colored dark by a neutral litmus solution is placed on an object glass and cooled. If a carefully cut and polished surface of the mineral is now laid on the gelatine plate, after 24 hours a picture of the structure of the mass is drawn on the gelatine by the action of local currents.

Electrolytic action is obtained and observed under the microscope by use of a small galvanic element or microelectrolytic point consisting of an equilateral triangle of platinum about 15 mm. on a side and 2 mm. thick

soldered to a triangle of zinc about 10 mm. on a side and 5 mm. thick. The point of platinum is placed touching the crystal and a drop of HCl added, so that both points are in it. In this way, for instance, cassiterite becomes black and opaque from a coating of tin, while the very similar zircon and xenotime are not affected. So also chalcopyrite becomes black, pyrite and pyrrhotite do not.

A. J. M.

HARDNESS.

Microsclerometer, for determining Hardness of Minerals.—T. A. Jaggar, Jr.—*Amer. Jour. Sci.*, IV., Vol. IV., 399, 1897; also in *Zeit. f. Kryst.*, XXIX., 262.

The hardness of minerals has been investigated by the following methods: (1) Abrasion, (2) Penetration, (3) Friction, (4) Fracture; all designed to measure the resistance which a substance opposes to permanent deformation. Of these investigations nearly 76% were made by abrasion, all the investigators but one being mineralogists. The remaining investigations were made by penetration and fracture tests, the investigators being physicists and metallurgists. To these latter results objection has been made on account of the interference of tenacity and plasticity.

The definition of "Hardness" given by the author and generally accepted by mineralogists is that, "it is the resistance offered by a smooth surface to abrasion." (Dana.)

The author has designed a sclerometer which can be applied to a microscope, thus making it available for either thin sections or crystal faces. The apparatus is fully described in the text (three cuts). The idea has been to eliminate as far as possible the following chief sources of error in former instruments: (1) personal variability due to using "visibility" as determinant; (2) inequalities of mineral surface; (3) undefined details of instrument.

The quality proposed to be measured by the instrument is the resistance opposed by a body to the removal of particles of its substance by a defined diamond point, moving in contact with it under uniform conditions.

The principle of the instrument is as follows: A diamond point of constant dimensions (cleavage tetrahedron) is rotated on an oriented mineral section under uniform rate of rotation and uniform weight to a uniform depth (measured by focusing on the rulings of a Zeiss micrometer glass, which is slightly inclined and follows the downward movement of the diamond point). The number of rotations of the point, a measure of the duration of the abrasion, varies as the resistance of the mineral to abrasion by diamond.

The measurement may be based on any one of the four variables —rate, weight, depth or duration; the last being found most practical as it gives the highest values and hence admits of the most delicate gradation.

The calibration of the instrument will be described, in greater detail, by the author in a later paper.

Sclerometric values of the Mohs scale as obtained by author:

9. Corundum,	1000	5. Apatite,	1.25
8. Topaz,	152	4. Fluorite,	.75
7. Quartz,	40	3. Calcite,	.26
6. Orthoclase,	25	2. Gypsum,	.04

The relatively greater differences in hardness between the members of the scale, towards the upper end, should be noticed.

Suggestions as to the use of the instrument for other purposes are given by the author at the close of the article.—L. McI. L.

Ueber eine anscheinend nothwendige Erweiterung der Theorie der Elasticität.—W. Voigt.—*Wied. Ann.*, LII., 536–555.

Die Härtescala in absoluten Maase.—F. Auerbach.—*Wied. Ann.*, LVIII., 57. Tabulation of results by method of pressing a lens of substance upon a plate of the same substance.

Sur les figures inverses de dureté.—H. Buttgenbach.—*Ann. Soc. Geol. de Belg.* XXIII., 29–32, 61–66; *Neues Jahrb. Min.*, 1897, II., 437, Ref. Continuation of the Cesaro study of the inverse hardness curves, based on data of Exner's experiments.

Determinations of hardness with the Usometer.—P. Jannetaz v. M. Goldberg.—*Ass. franc. p. l. avanc. d sc.*, IX. Abst. *Zeit. f. Kryst.*, XXVIII., 103. The Usometer consists of a rotating grinding disc upon which four plates, the hardness of which are to be determined, are pressed by normally acting weights, the loss of weight of each giving the relative hardness.

ETCHING.

Triclinic Minerals, examination of by etching Figures.—T. L. Walker.—*Am Jour. Sci.*, IV., Vol. V., 76, 1898.

Etching figures indicate the symmetry of the crystalline surface on which they occur. Experiments made by the author confirm the statement that "crystal faces belonging to the same crystal form give identical or similar etching figures, while faces belonging to different crystal forms give different etching figures, even if the faces be parallel to each other; or conversely, if parallel faces give different etching figures, the faces do not belong to the same crystal form." Tests were made on basal planes of tourmaline (hemimorphic hexagonal) and acid dextro-tartrate of strontium (asymmetric triclinic). Etchings were obtained on the former by treatment with red-hot fusion of $KHSO_4 + CaF_2$, and on the latter by slight pressure of a rag moistened with water.

By etching tests the following triclinic minerals were proved to be centro-symmetric or holohedral; axinite, cyanite, chalcanthite, rhodonite and albite.

The tests developed no reason for departing from the opinion of Baumhauer and Becke that "the surfaces of etching figures are never curved but always plane."—L. McI. L.

Aetzfiguren am Gyps.—C. Viola.—*Zeit. f. Kryst.*, XXVIII., 573 (with plate).

Atzversuche am Kalkspath.—Axel Hamberg.—*Geol. För. Förh.*, XVII., 53, 453, 1895; *Neues Jahrb. Min.*, 1896, I., 216 Ref.

Ueber die Aetzfiguren einiger Mineralien.—H. Traube.—*Neues Jahrb. Min*, Beil. Bd., X., 454, 1895–6.

Gives examples of minerals the etch figures upon which point to a *higher* symmetry than the geometric form.

Cuprite the face 986 of Miers indicates plagihedral hemihedry, but etch figures indicate holohedry.

Phosgenite etch figures indicate holohedry.

The symmetry for certain other species as determined by etch figures:

Wulfenite and scheelite pyramidal hemihedry.

Tobernite, cyanite, beryl, holohedral.

Tourmaline hemimorphic tetartohedral.

Dioptase, willemite rhombohedral tetartohedry.

The etchings on tourmaline and other refractory minerals were obtained by evaporating a solution of KOH to a paste, pressing the crystal face into it and maintaining for some time at a temperature of 100° to 150° C.—A. J. M.

Relations between Form and Composition.

Ueber den Zusammenhang zwischen den krystallographischen Eigenschaften von isomorphen Salzen und dem Atomgewicht der darin enthaltenen Metalle, etc.—A. E. Tutton.—*Zeit. f. Kryst.*, XXVII., 113, 252, 266, XXIX., 63.

Beiträge zur Kentniss des Isomorphismus.—J. W. Retgers—*Zeit. f. physik. Chemie*, XIV., 1–52, XV., 529–587, XVI., 577, XX., 481–546. *Neues Jahrb. Min.*, 1896, II., 405, Ref., 1897, II., 439 Ref.

Einige Beiträge, zur Kentniss der isomorphen Mischkrystalle.—H. Ambronn, and M. Le Blanc.—*Ber. Sächs. Ges.*, July 2, 1894; *Neues Jahrb. Min.*, 1896, I., 206, Ref.

Beiträge zum Isomorphismus der Alkalisalze.—B. Krickmeyer.—*Zeit. f. Phys. Chemie*, XXI., 53.

Sur l'isomorphism optique des feldspaths.—F. Wallerant.—*C. R.*, CXXI., 740.

Concludes from calculation of optical constants of soda lime feldspars as functions of albite and anorthite and comparison with Fouqué's measurements, that there is no true optical isomorphism and that the molecules of albite and anorthite are chemically combined.

Zur Theorie der Plagioklasmischung.—C. Rammelsberg—*Neues Jahrb. Min.*, 1896, II., 165.

Tabulates results of different analyses, giving ratio of Al to Si and Na to Ca in examinaton and support of the law of Tschermak "All plagioclase feldspars are isomorphous mixtures of albite and anorthite."

Einfluss der chemischen Constitution organischer Stoffe auf ihre Fähigkeit, feste Lösungen zu bilden.—F. Garelli.—*Zeit. f. Phys. Chemie*, XVIII., 51, abs., *Zeit. f. Kryst.*, XXIX., 174.

With substances of known molecular weight the capacity to form mixed crystals can be ascertained by determining molecular weight of crystals obtained by Raoult's freezing point method.

Zur Bestimmung der Grösse des Krystallmolecüls.—A. Fock.—*Ber. d. D. Chem. Ges.*, XXVIII., 2734; *Neues Jahrb. Min.*, 1896, II., 407, Ref.

Considering isomorphous mixture as solid solution (feste Lösungen) the size of the crystal molecule can be ascertained. For certain inorganic salts the crystal molecule is identical with the chemical, for others is formed by combination of two chemical molecules.

Beiträge zur Moleculargewicht bestimmung an krystallisirten Substanzen. —W. Würfel.—Dissertation. Marburg, 1896; *Neues Jahrb. Min.*, 1897, II., 251, Ref.

Tending to further prove that the crystal molecules of certain carbon compounds are only the same or double the size of the gas or chemical molecule.

Ueber die Löslichkeit Mischkrystallen und die Grösse des Krystallmolekuls.—A. Fock.—*Zeit. f. Kryst.*, XXVIII., 337.

Ueber küntsliche Färbung von Krystallen und amorphen Körpern.—O. Lehmann.—*Wied. Ann.*, LI., 47–76, 1894.

Many organic coloring substances appear to combine to "mixed crystals" with chemically non-analagous substances, the resultant crystals often being dichroic.

Beitrag zu den Beziehungen zwischen dem Krystall und seinem chemischen Bestand.—G. Linck.—*Zeit. f. Phys. Chem.*, XIX., 193, 1896. *Neues Jahrb. Min.*, 1896, II., 401, Ref.

Beitrag zur Kentniss eutropischer Reihen.—W. Ortloff.—*Zeit. f. Phys. Chemie*, XIX., 201, 1896; *Neues Jahrb. Min.*, 1896, II., 401, Ref.

Just as elements can be arranged in periodic system because their properties appear to be functions of their atomic weight, so the crystals of elements and combinations can be arranged in periodic series such that similar geometrical and physical characters repeat themselves.

Members of eutropic (regular change) series are only distinguished in that they contain different elements similar accoroing to periodic system.

e. g., Aragonite and strontianite are eutropic, but aragonite and cerussite are not eutropic but are called morphotropic.

Isotypie bei chimisch einfachen Körpern und der Carborund.—F. Rinne.—*Neues Jahrb. Min.*, 1897, II., 1.

Die Krystallformen chemisch einfacher Körper. Nebst einigen Bemerkungen über Ausführungen des Herrn Retgers.—F. Rinne.—*Zeit. f. Phys. Chemie*, XVI., 529; *Neues Jahrb. Min.*, 1896, II., 399, Ref.

Chemically simple (monotomic to triatomic) substances crystallize preferably in hexagonal or isometric system, those in hexagonal can be grouped in types of quartz, arsenic and magnesium.

Synthesis.

Synthese einiger Erzmineralien und analoger Metallverbindungen durch Auflösen und Krystallisirenlassen derselben in geschmolzenen Metallen.—F. Rössler.—*Zeit. f. Anorg. Chemie*, IX., 31; *Neues Jahrb. Min.*, 1897, I., 230, Ref.

Sulphides, arsenides and similar compounds can be separated in crystals from a molten metal when of higher fusing point. If more easily fusible they separate as drops and show no crystals on solidification. A number of species are described obtained as crystals by this method.

Eine allgemeine Methode zur Darstellung von Metallsulfiden auf Elektrochemischen Wege.—R. Lorenz.—*Zeit. f. Anorg. Chemie*, XII., 442; *Neues Jahrb. Min.*, 1897, II., 441, Ref.

Cathode of Copper Sulphide, Anode of the metal, solution of potassic nitrate or chloride.

Versuche zur Herstellung von Sulfantimoniten und Sulfarseniten des

Silbers auf trockenem Wege.—H. Sommerlad.—*Zeit. f. Anorg. Chemie*, XV., 173–179; *Neues Jahrb. Min.*, 1898, I., 459, Ref.

Versuche über kunstliche Darstellung von Gesteinen unter Zugabe von Schmelzmitteln.—C. Doelter.—*Neues Jahrb. Min.*, 1896, I., 211.

Synthetische Studien.—C. Doelter.—*Neues Jahrb. Min.*, 1897, I.

By smelting certain minerals (in Fourquignon furnace) crystalline products corresponding to other species were obtained. For example:

Muscovite, lepidolite and zinnwaldite give leucite and sometimes crystals resembling nephelite.

Biotite gave augite, spinel and chrysolite.

Clinochlore gave augite and chrysolite.

Tourmaline gave chrysolite, spinel and anorthite.

Axinite and epidote gave diopside and anorthite.

Zoisite gave garnet.

Rhodochrosite, artificial production of.—A. de Schulten.—*Bull. Soc. Min.*, XX., 195, 1897.

Phosgenite, Cerusite and Laurionite, Simultaneous artificial production of.—A. de Schulten.—*Bull. Soc. Min.*, XX., 194, 1897.

Phosgenite, Artificial production of at ordinary temperature.—A. de Schulten.—*Bull. Soc. Min.*, XX., 191, 1897.

Transparent tetragonal prisms or pyramids with bright luster, obtained by exposing an aqueous solution of chloride of lead to the action of carbonic acid gas.—L. McI. L.

Künstlichen Kassiterit.—A. Arzruni.—*Zeit. f. Kryst.*, XXV., 467.

Notice cristallographique sur la cotunnite artificiell.—F. Stöber.—*Bull. de l'Acad. roy. de Belg.* (3), XXX., 345, *Neues Jahrb. Min.*, 1897, II., 275 Ref.

Reproduction artificielle de darapskite et de l'hydrargilite.—A. de Schulten.—*C. R.*, CXXII., 1427, *Neues Jahrb. Min.*, 1897, II., 276, Ref.

Nouvelles expériences sur la reproduction der diamant.—Henri Moissan.—*Bull. Soc. chim. Paris*, S. 3, XI., XII., 840–845, *Neues Jahrb. Min.*, 1896, I., 209, Ref.

The melted iron from electric furnace falls into a vessel containing mercury and water, the granulated metal consists of little spheres or spheroids of not over 1 cm. diameter containing black or colorless diamond, sometimes in very regular crystals, or better poured into a cylindrical hole in a block of iron or copper, which is quickly closed by a cylinder of the same metal.

Recherches sur les différentes varietés du carbone.—H. Moissan.—*Ann. de Chim. et de Phys.*, VIII., 289, 306, *Neues Jahrb. Min.*, 1897, II., 6, Ref.

Sur la preparation d'une variété de graphite foisonant.—Henri Moissan.—*Bull. Soc. Chim. Paris*, S. 3, XI., XII., 837, *Neues Jahrb. Min.*, 1896, I., 210, Ref.

Gehlenit und Wollastonit krystalle in Schlacken von Pribram.—Ph. Heberdey.—*Zeit. f. Kryst.*, XXVI., 19.

Synthesis of Hanksite.—A. Lacroix.—*C. R.*, CXXIII., 1325, abs. *Zeit. f. Kryst.*, XXIX., 415.

Reproduction artificielle simultanée de la northupite, de la gaylussite et de la pirssonite.—A. de Schulten.—*C. R.*, CXXIII., 1023–1025.

Künstliche Antimonit und Wismuthkrystalle, aus der k. k. Hütte in Pribram.—P. Heberdey.—*Ber. Ak. Wien.*, CIV., 254, abs. *Zeit. f. Kryst.*, XXIX., 304.

Ueber die Darstellung von künstlichen Skorodit.—H. Metzke.—*Neues Jahrb. Min.*, 1898, I., 169.

Synthetische Versuche in der Topasreihe. — A. Reich. — *Ber. Ak. Wien.*, Feb. 13, 1896, *Neues Jahrb. Min.*, 1898, I., 460, Ref.

Influence of a High Temperature on Some Sulphides.—A. Mourlot.—*C.R.*, CXXIII., 54, abs. *Zeit. f. Kryst.*, XXIX., 412.

Galenite obtained in sharp cubic crystals by heating amorphous PbS in a small moissan electric furnace.

Similarly from the amorphous compounds obtained crystals of stibnite, wurtzite, greenockite.

Ueber reguläre Kieselsäurekrystalle.—K. v. Chrustschoff.—*Bull. Ac. Sc. St. Petersburg*, Jan., 1895, 27.—*Neues Jahrb. Min.*, 1897, I., 240.

At temperature 200° C. and pressure 26 atmospheres amorphous silica was converted into christobaltite.

Sur le sulfure de manganèse anhydre crystallisé.—A. Mourlot.—*C. R.*, CXXI., 202.

Alabandite obtained by smelting amorphous MnS with a little sulphur in an electric furnace.

SUNDRIES.

Über das Vorkommen von Ammoniak-Stickstoff im Urgestein.—H. Erdmann.—*Ber. d. D. chem. Ges.*, XXIX., 1710; *Neues Jahrb. Min.*, 1897, II., 252, Ref.

Nitrogen, as an ammonia compound, in two new minerals from Finland to be later described by Ramsay.

Versuche zur Darstellung neuer schwerer Flüssigkeiten zur Mineral trennung I. Die Acetate der Schwermetalles als schwere Schmelzen.—J. W. Retgers.—*Neues Jahrb. Min.*, 1896, I., 212; II. Die Nitrate und Doppel nitrate.—*Ibid.*, II., 183.

Zur mikrochemischen Untersuchung einiger Minerale aus der Gruppe der Lamprite.—J. Lemberg.—*Zeit. d. D. geol. Gesell.*, XLVI., 788; *Neues Jahrb. Min.*, 1896, II., 227, Ref.

Sulphides, arsenides, etc., yield adhesive sediments upon the mineral when treated with either an alkaline bromine solution prepared by a solution of 4 gms. KOH in 25 cc. bromide solution; or with a cold saturated solution (100 cc.) of Ag_2SO_4 with 5g H_2SO_4.

Aenderungen in Einigen Mineralien und Salzen unter dem Einfluss von Kathodenstralen, oder von Natriumdampfen.—F. Kreutz.—*Anzeiger d. Ak. Wiss.*, März, p. 112; *Neues Jahrb. Min.*, 1897, I., 3, Ref.

Under influence of cathode rays sodalite of Turkestan and Wodokolansk becomes violet to cherry red and remains so for six or eight days, cryolite becomes temporarily black, decolorized blue fluorite of Cumberland becomes violet.

In the same way, or if heated in sodium vapor, potassium haloids containing a trace of iron become blue.

Das Wesen der Krystalliten.—H. Vater.—*Zeit. f. Kryst.*, XXVII., 505.

"Crystallites are rigid molecular mixtures of two or more substances, and attain, by the crystalline forces of these substances, a more or less regular molecular arrangement and, with free development, also regular forms, The molecular arrangement and forms of the crystallites differ, however, from those of crystals built from equivalent molecules, because of the inequality of the crystalline forces of the component substances. Especially they differ in curved faces instead of plane."

Das mikroskopische Gefüge der metalle und Legirungen.—H. Behrens. —1894, 177 pp., 16 plates, abs. *Zeit. f. Kryst.*, XXVII., 534.

Microscopic study of crystals and crystalline facets formed in solidification of alloys and metals.

Noveau mode de production de cristaux transparentes.—C. de Watteville.—*C. R.*, CXXIV., 400; *Neues Jahrb. Min.*, 1898, I., 459, Ref.

By rotating the crystal during its growth it becomes as transparent and brilliant as a cut precious stone.

Darstellung grosser Kalk und Strontian krystalle.—G. Brügelmann.—*Zeit. f. Anorg. Chem*, IX., 415; abs. *Zeit. f. Kryst.*, XXIX., 300.

Ueber den Einfluss der Zeit auf das Zusammenschweissen gepresster Kreide.—W. Spring.—*Zeit. f. Anorg. Chemie*, XI., 160, 1896; *Neues Jahrb. Min.*, 1897, II., 250, Ref.

Dry pulverized chalk, after seventeen years in a screw press, under the highest obtainable pressure, showed conchoidal fracture and on the surface had a hardness almost of marble. Microscopic particles in the surface showed crystalline properties.

Über den Einfluss des Druckes aut die Reactionsgeschwindigkeit.—V. Rothmund.—*Zeit. f. phys. Chemie.*, XX., 168; *Neues Jahrb. Min.*, 1897, II., 437, Ref.

Exerts retarding influence.

Pressure during the action of water upon apophyllite, quartz and glass. —G. Spezia.—*Atti. Ac. Sc. di Torino*, XXXI., 245; XXX., 29, 196, abs. *Zeit. f. Kryst.*, XXVIII., 200.

Pressures of 1750 atmospheres five to six months at 25° C. produced no signs of solution upon apophyllite or quartz, and with glass the pressure produced so little effect that little more was dissolved in four days than with pressure of only 1.7 atmospheres.

Ueber das Zusammenfliessen und Ausheilen fliessend-weicher Krystalle. —O. Lehmann.—*Zeit. f. phys. Chemie*, XVIII., 91, *Neues Jahrb. Min.*, 1897, I., 226, Ref.

If some potash soap is dissolved in a drop of alcohol on the stage of microscope there result pointed octahedral crystals, tetragonal optically. If two small crystals touch they usually unite to a greater like two drops of a liquid. Larger crystals unite slowly, the smaller turning into parallel position to the larger. If by pressure a large crystal is split into fragments these all take symmetrical forms and become individual crystals.

Ueber die Durchgangsflächen des Eisenglanzes und des Diopsids.—P. Jeremejew.—*Verh. d. russ. k. min. Gesell.*, XXXIII., 19, *Neues Jahrb. Min.*, 1898, I., 18, Ref.

Concludes that these planes of separation are not necessarily results of pressure or secondary phenomena after the formation of the crystal.

Ueber den Einfluss der Lösungsgenossen auf die Krystallisation des Calciumcarbonats V.—H. Vater.—*Zeit. f. Kryst.*, XXVII., 477.

Glastafel für Löthrohrproben.—V. Goldschmidt.—*Zeit. f. Kryst.*, XXIX., 33.

For use in recognizing colors of borax and salt of phosphorus, prepares a four column series (Borax O. F., Borax R. F., Ph. S. O. F., Ph. S. R. F.) of glass tablets of proper color.

Device for deliquescent minerals in collections. H. Laspeyres.—*Zeit. f. Kryst.*, XXVII., 45. A glass plate with gutter over which a glass is placed and the gutter filled with a mass made of equal parts wax, colophonium and paraffin.

Densities of Solids, Accurate Method of Determining.—Earl of Berkeley.—*Min. Mag.*, XI., 64, 1895. Pyknometer used with thermometer stopper and capillary at side. Crystals are powdered and density can be obtained to $\frac{1}{2000}$.

Separation of Minerals of High Specific Gravity.—S. L. Penfield.—*Am. Jour. Sci.*, III., Vol. L., 446, 1895.

Nitrates of silver and thallium (Retger's double salt) when mixed, in proportion $AgNO_3 : TlNO_3 = 1:1$, yield a double salt which fuses at about 75°C. to a clear mobile liquid with sp. gr. of over 4.5, and while melted is miscible with water in all proportions.

New form of separating apparatus described, consisting of a glass tube, open at bottom, fitting into a small cup, and being itself fitted internally with a long glass stopper.

Not safe to apply method to separation of sulphides.—L. McI. L.

Percussion Figures, on Cleavage Plates of Mica.—T. L. Walker.—*Amer. Jour. Sci.*, IV., Vol. II., 5, 1896.

Measurements on twenty different micas proved that the lines forming the star of the percussion figure do not intersect at 60°, the angle between the two lines, supposed to be parallel to the prismatic edges of the basal section, varied from 52°53′ to 63°28′; hence they cannot be parallel to these edges as previously considered.

Direct Spectrum Analysis of Minerals.—A. de Gramont.—*Bull. Min. Soc.*, XVIII., 171.

Two small fragments of the mineral to be tested are held in platinum pincers, connected with condenser, and a spark passed between them. The elements are dissociated (by sparks) and give their characteristic spectrum lines.

The author gives description of: 1° apparatus for producing sparks; 2° spectroscope; 3° preliminary observations, the spectra of the elements, etc.

The Constitution of the Silicates.—F. W. Clarke.—*Bull. U. S. Geol. Survey*, 1895, CXXV., 1–109.

ALUMNI AND UNIVERSITY NEWS.

DEPARTMENT OF MINING.

The Summer School of Mining, of 1898, was held in the bituminous mines of the noted Pocahontas, or Flat Top, coal field, situated in the extreme southerly part of West Virginia, and in the iron and zinc deposits of the Cripple Creek district, near Pulaski, Virginia.

To arrange for the session Adjunct Professor Peele left New York on May 24th, and was joined by the class on the 28th. The headquarters of the school was established at Bramwell, W. Va., near which are situated the mines of the Caswell Creek Coal and Coke Company. These mines are owned largely by the family of Mr. James Ellwood Jones, class of '95, S. of M., from whom, it should be stated, had come a cordial invitation to visit the region. The class consisted of eleven students, ten of the fourth year, and one an 1898 graduate in civil engineering. Professor Peele was assisted by Messrs. Alex. J. Campbell and Charles Of, the former having charge for the second time of the Summer School mine surveying, the latter taking part in the surface and underground work of the class.

The regular detail work was begun on May 30th, at the Caswell Creek mines, and occupied about three weeks, including the surveying. In these mines the main Pocahontas seam is worked, the present production being about 18,000 tons per month. Were it not for the temporary inability of the railroad to supply enough coal cars, the production would be at least 24,000 tons per month. The deposit is nearly flat, outcropping on the slopes of the hills at some height above the creek bottoms. All the mining of the district is done by the double-entry, room and pillar system. As the pillars are robbed in such a way as to save from 80 to 85 per cent. of the coal, the roof is allowed to fall at once, and very little timber is used.

The Pocahontas seam is the third of a series of ten or eleven veins found in the Flat Top region, and is the only one worked up to the present time. Generally throughout the field this seam measures from seven to ten or twelve feet in thickness, while the others of the series are only a few inches to three or four feet thick. Most of these are entirely too thin to be considered workable, even under the exceptionally favorable conditions existing in the district. It is interesting, though not satisfactory, to note that several of the minor seams, which are thick enough to become available in the not very distant future, overlie the main vein, and in working the latter they are being, in large part, practically destroyed. This is due to the unavoidable caving in of the roof of the mine, as fast as the pillars are robbed The cracks and dislocations thus caused extend nearly always to the surface, and seriously injure and break up the overlying veins.

Along the southeast margin of the field the coal measures are sharply upturned, and pinch out completely in a straight, well-defined fold, running from northeast to southwest. This anticline becomes a fault towards the southwest. From the fold the average dip, or pitch, of the measures is about one and one-half per cent. toward the northwest, until

finally the Pocahontas seam disappears below water level a little beyond the Tidewater mine, on the Norfolk and Western Railroad. No coal is being mined at present beyond this point. As all the mines are opened by adit levels little or no pumping is necessary, and the heavy expenses incident upon shaft mining are avoided. It is not probable that the great unexplored areas of coal lying below water level will be developed until the more cheaply and easily mined portions above water level begin to show signs of exhaustion.

On completing the class work at the Caswell Creek mines short visits of from one to two days each were made to the large mines of the Southwest Coal and Coke Company, at the town of Pocahontas, and to the Peerless, Norfolk, Angle, Pulaski, Crozer and Turkey Gap mines, situated on Elkhorn River, along the main line of the Norfolk and Western Railroad. At the various mines a variety of work was presented for observation and study. The operations are conducted on a large scale, and while, owing to the uniformity of the natural conditions, the method of mining is the same in all, the machinery plants vary greatly. Underground haulage is done by mules, and by steam, electric or compressed air motors. The coal is mined either by hand or by electric coal cutters, most of which are built by the Jeffrey Manufacturing Company, of Columbus, O. At one mine, the Peerless, where compressed air haulage is employed, it is proposed to introduce coal cutters operated by compressed air. Each mine has its own coke oven plant, most of the ovens being of the bee-hive type. Several blocks of Welsh ovens were built some years ago, but have been either abandoned or altered to work like the bee-hive ovens. At the Southwest mine, Pocahontas, a few ovens have been recently remodeled for the saving of the bye-products. Although at the time of our visit the bye-products were being treated only on an experimental scale it seemed probable that the trial would prove successful. The charges of these ovens are drawn by mechanical means.

On June 25th the class was taken to Pulaski, Virginia, from which place visits were made to the Bertha Zinc Mine, Wythe Zinc, Iron and Lead Company's mines, and the Cedar Run iron mines. These comprise mainly surface workings, and are in what is known as the Cripple Creek district, on the North Carolina branch of the N. and W. Railroad. The soft hematite ores of the region are almost wholly superficial, though of great extent. Most of the ore is of low grade, requiring a rough washing to produce a marketable product. At the Wythe mine the class had the opportunity to see a very well arranged zinc concentration plant comprising trommels, hydraulic separators and jigs. One day, also, was spent at the Bertha zinc furnaces and the Pulaski iron furnace. This completed the five weeks allotted to the mining work of the summer school. On July 2d the class was met at Pulaski by Professor Kemp, and started north to Buena Vista, Va., for the usual field geological work.

Through the influence and kind offices of Mr. James E. Jones, and of his father, Mr. Jenkin Jones, the manager of the Caswell Creek mines, every facility was afforded for carrying on the class work. To them, and to Messrs. J. J. Tierney, President of the Pocohontas Coal Association, and J. M. Barr, General Manager of the N. and W. Railroad, the class is indebted for railroad passes, while making the daily trips during the fourth week of the session, from Bramwell to the mines

on Elkhorn river. The names of all those from whom we received kindnesses would make a very long list. But it is desired to record here the warm welcome given us by the Messrs. Jones and all the members of the staff at the Caswell Creek mines; also the kindness of Messrs. S. M. Buck, C. R. Buck, H. B. Wright, S. F. Morris and W. Lang, of the coal fields, and of Messrs. Holstein, McKee, J. C. Raper and J. W. Eckman, of the Pulaski district.

DEPARTMENT OF CIVIL ENGINEERING.

The course in Civil Engineering has been developed, since that department was established, so as to justify the broad and historic sense of the title. That development has not been limited by the narrow view that Civil Engineering covers only matters of statics, but rather to meet the requirements of the general view which makes Civil Engineering cover all engineering not distinctly military or naval. This requires that the mathematical and mechanical basis of the course shall be both comprehensive and thorough. It further requires that the special applications of mechanics shall be made so as to cover the foundation principles of the transformation and use of energy or power in the fields of water, steam and electric motors as well as the treatment of hydraulic and structural work in the broadest sense of the terms. In other words it is believed that the most effective and useful course in Civil Engineering must not be one in which the profession of the civil engineer is regarded as a specialty.

The course in Civil Engineering at Columbia as it is now established is intended to meet these advanced requirements in such a way as to enable its graduates to attain to the best quality of professional work. The first two years may be regarded as preparatory, in a mathematical and physical way, for the real technical work of the last two years. During the last half of the course, a very complete treatment is given to the theory and design of the structures and machines which a civil engineer must construct or the operations of which he must control and direct in his subsequent career as a professional man. The lecture hours are devoted to the analytic treatment of technical subjects, so that the theories underlying the correct design of structural works or of machines are thoroughly understood. In the design work of the drafting rooms and in the laboratories those theories find continuous applications in designing operations and in other practical work which in general is of a character as nearly identical with that which belongs to the actual office, field and shop work of the civil engineer as it is possible to attain in the work of instruction.

The field operations in surveying are unusually extended and the greatest care is exercised both in the taking of field notes and in the subsequent map making. In the design work actual data are taken and working specifications governing current engineering work are employed, so that the working drawings which are completed by the students are practically identical with those under which shop and field work are executed. In this manner such works as railroad surveys, hydraulic gauging, retaining walls, tall chimneys, high masonry dams, arches, long span bridges, viaducts, buildings, engines, pumps, various classes of elec-

trical work and other similar structures and machines are subjected to the same operations of study and design as in actual engineering practice.

The general character of the course in Civil Engineering has been improved this year by the introduction of a substantial amount of electrical engineering work in the third year. By this addition the course as a whole acquires a very desirable proportion of electrical work. The increased facilities afforded to all the departments of engineering at the new site has however only made it possible at this time to effect the desired improvement. This together with the additional laboratory facilities which are now available to the department gives the complete balance in all professional directions which is necessary for a broad and advanced course of Civil Engineering study.

The adjunct professorship was filled on the first of July last by the appointment of Mr. Earl B. Lovell, C.E., who previously had been instructor in Civil Engineering at Cornell University, and prior to that work, had been engaged a number of years on the Michigan Central Railroad in various capacities on location, construction and maintenance of way. Professor Lovell has immediate charge of the Summer School of Surveying, which has been located for a number of years near Morris, Litchfield county, Conn. During the past three years the tutorship of Civil Engineering had been filled by Mr. A. Black, C.E., of the class of '94 School of Mines, while Mr. Charles Derleth, Jr., B.S., C.E., class of '96 School of Mines, has been assistant in Civil Engineering since his graduation.

The departmental work has been interrupted in some of its laboratories in consequence of the movement from the old site to the new. The laboratory work in cements and mortars, however, has suffered no break, but was indeed somewhat extended in the course given last year. It will be still further extended during the current year, facilities having been installed for accelerated and other special tests. During the year just closed, investigations connected with thesis and other work were conducted for a number of special cements and their admixtures with sand and they will be continued during the coming year.

Laboratory work for the testing of materials was entirely suspended last year in consequence of the impracticability of re-installing the testing machines at the new site in time to make them available for the student's testing. The laboratory facilities will be applied during the coming year to the testing of various grades of materials used in engineering work by the students taking the course in the Resistance and Elasticity of Materials given in this department. These operations will be considerably extended and advanced in the coming year, corresponding in a measure to the increased facilities afforded in the new laboratory.

The hydraulic laboratory which was installed in this department at the old site of the University has been much elaborated and developed as a part of the Henry R. Worthington Hydraulic Laboratory. At the present time full plans have been completed for a wide range of work. The pumping machinery and other appliances in the Department of Mechanical Engineering will be available for supplying large volumes of water required for the flow over weirs, in open channels and through lines of regular service pipes up to probably 12 inches in diameter. These laboratory facilities will enable the students to take a complete set of practical exercises in all the usual measurements of water found in the hydraulic

engineer's practice, and with dimensions that will correspond at least approximately to those found in practice. Full provision is made for the determination of the various phenomena of flow in open channels. The department is already well supplied with such appliances as hook gauges, current meters, measuring tanks for meter testing and other similar operations. When the present facilities are supplemented by those now in process of design and manufacture, the operations of the hydraulic laboratory of the department will be productive of results of the highest value.

Instruction in the theory of surveying is given in full during the lecture periods at the University. The field work, however, is all given at the Summer School with the exception of the hydrographic survey which for the past two years has been very satisfactorily conducted on the Harlem River east of the Ship Canal. In developing both the theory and practical work of surveying it has been kept in mind that this work is at the foundation of a large portion of the field operations of Civil Engineering. The importance of this branch of instruction is recognized in the careful and thorough manner in which all surveying work is conducted at the Summer School. The equipment of field instruments is unusually complete, so that small field parties, usually of two students each, can be kept constantly at work during the period allotted for field operations. Each student is thus more readily impressed with his responsibility for accuracy, and at the same time he secures the advantages arising from almost constant use and handling of the instruments. Again, each student may thus be required to prove most satisfactorily his ability to undertake and complete the work assigned to him. Elementary exercises and problems are taken up in the Summer School between the first and second years. From that point the course is developed in natural sequence by the most approved methods of field practice in every branch of plane surveying. The office work is kept abreast of the surveys; maps, plans and profiles with specifications and estimates being prepared whenever practical work requires them. Both methods and results receive the most careful consideration. It is intended that the methods shall be those approved by experience and in the application of those methods careful supervision is given with the intention that the students shall be benefited by the experience of the instructors. The railroad survey completed during the past summer was about 2½ miles long. The work involved reconnaissance, preliminary and location surveys, together with running in curves, cross sectioning and all the operations requisite for the complete preparation of the line for the work of the contractor.

The entire work of the school was completed in a highly satisfactory manner in every respect. Among other things great care was taken to maintain the camp in a thoroughly sanitary condition, and it is a source of much satisfaction that not a case of sickness occurred during the entire session.

DEPARTMENT OF GEOLOGY.

The summer school in geology was held this year in the valley of the James River, and covered a stretch of country from a point about four miles east of Balcony Falls to Covington. The place was selected with the advice of Professor Harry D. Campbell, of Washington and Lee Uni-

versity. Professor Kemp met the class at Pulaski on the conclusion of their work with Professor Peele, and traveled with them to Lexington on Saturday, July 2. Sunday was spent in this beautiful university town and in visiting historic memorials of the Confederacy. Monday the party set out under the guidance of Professor Campbell, to whose many courtesies the success of the trip was very largely due. Beginning on the quartzites of the lower Cambrian at Balcony Falls, the class walked eastward on the Chesapeake and Ohio R. R. track, passing over lower and lower beds which were upturned in a great fold, until the contact with the old Archean gneisses was met. The gneisses form the core of the fold, and after a mile or more of cuts through them, the Cambrian quartzites were again met dipping in a direction opposite to the first set. The class then returned to Balcony Falls and passed the night. The next day they walked across Upper Cambrian and Siluro-Cambrian limestones to the Natural Bridge, where all were profoundly impressed with the geological lesson which it illustrated. The evening found all established at Eagle Mountain at the mouth of one of the narrow gorges by which the James has cut its way across the ridges of the Appalachians. Beginning in fossiliferous Trenton limestones of moderate dip, the class tramped across the upturned and overthrown quartzites of the Upper Silurian and saw one of the most remarkable cases of crumpled and overturned strata in the East. Proceeding to Clifton Forge in the evening, the following day was spent in studying the extraordinary anticline at the Iron Gate, whose arch is so perfect and so well shown that it is appropriately called the "Rainbow." The next morning all took the cars for the mines of the Low Moor Iron Co., at Dolly Ann near Covington, and, under the courteous guidance of Mr. H. C. Merry, the general manager of the company, went by special train to see the ore beds, where brown hematites are extensively dug from the Oriskany strata. The class was most hospitably entertained at luncheon by Mr. Merry, to whom Mr. A. A. Low, president of the company, had kindly given us introductions. Saturday was spent in a tramp from Covington to Low Moor along the railway and in studying the rich fossiliferous ledges of the Helderberg and Oriskany. A long trip underground in a fine cave at Low Moor concluded the work, and the class broke up with a vivid idea of Appalachian geology and of the structural problems which it affords.

Before joining the class Professor Kemp visited the famous granite knob of Stone Mountain near Atlanta, Ga., and later spent a week with L. D. Huntoon, '95, at Ducktown, Tenn., becoming acquainted with the geology of the copper ores. Some interesting minerals and collections of ores and rocks were obtained.

Soon after the close of the summer school Professor Kemp went to the Adirondacks and resumed field-work for the U. S. Geological Survey, with headquarters in the northern part of Essex County. He was accompanied by F. J. Pope, graduate student, who remained at work until the latter part of September. Professor Kemp also supervised work for the N. Y. State Geological Survey by D. H. Newland, formerly Fellow in Geology, and B. F. Hill, who now holds a scholarship.

Dr. Hollick attended the meeting of the American Association for the Advancement of Science in Boston in August, and read a paper on the fossils which have been discovered in the glacial drift on Staten Island. The list is the result of years of collecting and observation especially by

Dr. Hollick and Dr. Britton, and numbers 130 Paleozoic and 35 Cretaceous and Tertiary species. The fossils give some interesting information regarding the movement of the ice sheet. Dr. Hollick has continued his study of the Cretaceous strata around Long Island Sound and has explored the Elizabeth Islands during the summer, and has made some new discoveries of fossil plants on Martha's Vineyard. He has also read the page proof of a monograph of the U. S. Geological Survey, based upon MSS and plates left in an unfinished state by the late Professor J. S. Newberry. Dr. Hollick has revised and completed it and brought it to final issue.

Mr. J. D. Irving, fellow in geology, has been in the Black Hills all the vacation working on his thesis for Ph.D. He has found a most complex and interesting series of eruptive rocks, and has accumulated some very valuable data on the geology of the siliceous gold ores of the region. It is expected that the thesis will be completed during the winter.

DEPARTMENT OF MINERALOGY.

Dr. Egleston, Professor Emeritus, has presented to the department his personal collection of about 5,000 mineral specimens. These will be sent to the museum in December and gradually intercalated in the regular collections. Each specimen will be labelled "Egleston Collection." It is hoped that this very valuable gift can be carefully described in a later number of the QUARTERLY.

Dr. Egleston has also presented to the department a complete set, 156 volumes, of the *American Journal of Science*, and 80 volumes of miscellaneous works on mineralogy and crystallography.

The department also wishes to announce the presentation of a portrait of Dr. Egleston, which has been hung in the mineralogical museum. The portrait was the gift of several of his former associates in mineralogical work.

PRELIMINARY EXPERIMENTS IN THE COURSES IN PHYSICAL CRYSTALLOGRAPHY.

In order to secure more systematic work in the courses in physical crystallography, the following outline of experiments has been prepared. In the short course for organic chemists of the fourth year, the starred tests (*) are omitted because of insufficient time.

In the courses for graduate students these tests are followed by investigation of the crystals of a definite substance or isomorphic group in which the student prepares the material, determines the various geometrical and optical constants, and, so far as possible, the other physical constants, and the proper place of the crystals in the 32-group classification.

A. GEOMETRICAL CHARACTERS.

1. MEASUREMENT of CRYSTALS. Text,* pp. 62–75.
   (*a*) With horizontal circle goniometer. Babinet or Fuess.
   (*b*) With vertical circle goniometer. Wollaston, Mallard or Groth.
   *(*c*) With two circle (theodolite) goniometer.

* A. J. Moses' Characters of Crystals.

2. CRYSTAL PROJECTION OR DRAWING.

*(*a*) Stereographic projection. Text, pp. 20–24.

(*b*) Clinographic perspective. Text, pp. 76–84.

3. DETERMINATION OF ELEMENTS AND SYMBOLS in part by zone relations (Text, pp. 17–20), in part by calculation (Text, pp. 13–15, 28–30, 34, 38–39, 45–46, 55–56, 61–62).

B. OPTICAL CHARACTERS.

4. REFRACTION AND TOTAL REFLECTION. Text, pp. 86–90.

Graphic determination of direction of refracted ray and of ray incident at critical angle, the indices of refraction being known.

5. DOUBLE REFRACTION AND POLARIZATION. Text, pp. 97–100.

With mounted calcite rhombs, described p. 97.

(*a*) With one rhomb, two images equal intensity always in a principal section.

(*b*) If one of these images is stopped by a screen, and the other observed through a second calcite rhomb the variations in intensity of the two resultant images can be explained as a resolution of vibrations of definite length parallel (or perpendicular) to the principal section of the first rhomb, into components parallel and perpendicular to the principal section of the second rhomb.

6. DETERMINATION OF INDICES OF REFRACTION, with monochromatic light.

(*a*) Prism method. Text, pp. 88–90, 103, 146–147.

*(*b*) Total reflection methods. Text, pp. 90–95, 104, 147 (d).

*(*c*) Displacement method. Text, pp. 120.

If singly refracting the substance will yield the same index for all directions. If doubly refracting the principal indices will only be yielded in certain directions as decribed in text.

7. PRODUCTION OF POLARIZED LIGHT. Text, pp. 105–110.

(*a*) Examination of Nicol and Hartnack prisms (double refraction and total reflection), tourmaline pincers (double refraction and absorption), glass plate polarizers (reflection or refraction).

(*b*) Polariscopes (combinations of two polarizers), including older types Norremberg and later types Universal Apparatus, Polarizing Microscopes. Determine in each vibration plane of polarizers.

8. DETERMINATION OF EXTINCTION (VIBRATION) DIRECTIONS. Text, pp. 117, 145.

With polariscope (or polarizing microscope) and monochromatic parallel light, sections between crossed nicols are black when, Fig. 237, $\varphi = 90°, 180°, 270°, 360°$, midway between yield brightest illumination.

With white light use test plate gypsum red or special eye piece. Results are less accurate if there is marked dispersion.

The section, if too thick, will admit rays at directions not normal, preventing perfect extinction.

Use sections F. enstatite and pyroxene.

9. INTERFERENCE OF PLANE POLARIZED RAYS. Text, pp. 110–115.

(*a*) With monochromatic parallel light and crossed nicols extinction (throughout revolution) takes place when $\Delta = \lambda$, 2λ, 3λ, etc., for $\Delta = \frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, $\frac{5}{2}\lambda$ there is brightest illumination.

(*b*) With white parallel light Newton's colors of 1°, 2°, 3°, etc., order result.

Use sections quartz wedge, concave quartz 18^{40}, mica wedge, and mica 5^{22}, 5^{23}, 5^{24} 5^{25}.

10. DETERMINATION OF Δ AND $n_1 - n$. Text, pp. 118–119.

By v. Federow mica wedge, quartz wedge or Babinet compensator Δ results, check by color chart. Obtain $n_1 - n$ by formula $\Delta = t(n_1 - n)$, t being measured.

Use sections of tests 8 and 9.

11. DETERMINATION OF VIBRATION DIRECTION OF FASTER RAY. Text, pp. 118.

By test plate of mica or gypsum or by wedge of quartz or mica.

Use sections of tests 8 and 9.

12. OPTICALLY ISOTROPIC CRYSTALS.

Between crossed nicols, with either parallel or convergent light all sections remain dark throughout rotation. The index of refraction is independent of direction.

Use sections garnet 32^1 VH.1, 2, haüynite VH.4, nosite VH.5.

13. OPTICALLY UNIAXIAL CRYSTALS.

(*a*) Examination of models of positive and negative ray surfaces and indicatrices. Text, pp. 100–102.

(*b*) Examination of sections normal c between crossed nicols. In parallel light the section (if not too thick) remains dark throughout rotation. In convergent monochromatic light the arms of the cross remain fixed during rotation of the plate, the rings are wider apart in thinner sections, and with white light are colored in the order of Newton's colors, if space permits. Text, pp. 110–117.

Use sections zircon 15^3, quartz VH.7, 18^1, calcite VH.23, 21^1, 21^4, beryl 27^1, apatite 25^1.

(*c*) In sections parallel c obtain interference hyperbolæ in monochromatic light and approximate indices by displacement. Text, pp. 116.

Use sections calcite VH.24, quartz VH.8.

(*d*) In sections oblique to c. Text, pp. 110, 112, 116.

Use sections calcite 21^6, beryl 27^5.

(*e*) Determine character of ray surface by different methods. Text, pp. 120–121.

14. UNIAXIAL CRYSTALS IN WHICH c IS A DIRECTION OF CIRCULAR POLARIZATION. Text, pp. 122–130.

(*a*) Circular and elliptical polarization, with Fresnel rhombs.

(*b*) In sections normal c with parallel light.

Monochromatic, determine the direction and amount of rotation of analyzer to produce extinction.

White, note the sequence of colors on rotation of the analyzer.

(*c*) In sections normal *c*, with convergent light. Text, pp. 127.

Monochromatic, interference figure, giving the inter-wound spirals with ¼ undulation plate, or with two superposed sections.

White Light, interference figures with colored center, changing on rotation of analyzer in same sequence as for parallel light.

Use sections quartz, VH.7, 18^{2}, 18^{5}, 18^{13}, 18^{16}.

(*d*) Sections parallel or oblique to *c* essentially conform to 13 (*c*) and (*d*).

Use sections 18^{28}. Compare thickness of quartz wedges cut respectively parallel and normal to *c*, which give the same color.

15. BIAXIAL CRYSTALS.

(*a*) Examination of models of positive and negative ray surfaces and indicatrices. Given the three principal indices of refraction for yellow light to construct the three optical principal sections. Text, pp. 132–137.

(*b*) In sections normal to the acute bisectrix.

1. *In parallel light* essentially as in test 8. Also, relation of vibration (extinction) direction to cleavage or crystalline outline. Text, pp. 137, 138.

2. *In convergent monochromatic light* leminiscates depend upon thickness, but the distance apart of the axial points does not. Text, pp. 138, 139.

* 3. *In convergent white light* determine character of dispersion. Text, pp. 140–144. Examine models of dispersion.

4. Determine character of Ray Surface. Text, pp. 154.

Sections: aragonite 8^{4} 8^{5}, niter 8^{16} 8^{17}, cerussite 8^{13}, barite 8^{9}, calamine 7^{1}, topaz 8^{20}, 8^{22}, gypsum 5^{13}, titanite 5^{44}, diopside 5^{6}, orthoclase 5^{32}, borax 5^{1}, heulandite 5^{16}, muscovite 5^{19}, phlogopite 5^{18}.

(*c*) In sections normal to an optic axis in parallel monochromatic light there is a uniform illumination of the field, in convergent monochromatic light will be seen rings and one dark arm, which rotates in opposite direction to the stage. Text, pp. 137–139.

*16. ORIENTATION OF a, b and c, IN BIAXIAL CRYSTALS. Text, pp. 145, 146.

By extinction directions and interference figures in variously oriented pairs of parallel planes (natural faces, cleavages or planes obtained by grinding).

Use suite of sections or crystals of one substance.

17. DETERMINATION OF ANGLE BETWEEN OPTIC AXES. Text, pp. 148–154.

(*a*) By measurement of apparent angle in sections normal to the bisectrices either by rotation about b, with universal apparatus or its equivalent, in air or in a liquid of known index (text, pp. 148–150, 152), or by measurement of the distance apart of the emerging axes in a microscope or polariscope. Text, pp. 151.

(*b*) By measurement with entire crystal in a liquid of approximately or exactly the same index as the crystal. Text, pp. 151.

Use sections of muscovite and complete crystals.

18. ABSORPTION AND PLEOCHROISM. Text, pp. 96, 130, 131, 155–159.

In isotropic crystals there is no pleochroism, but there may be either color (unequal absorption) or no color (equal absorption). The absorption is independent of the direction.

In uniaxial crystals there is no pleochroism for transmission parallel c, but there may be pleochroism in other directions with greatest differences for transmission normal to c.

Use mounted cubes vesuvianite and tourmaline, Sections penninite 21^{10}.

In biaxial crystals the greatest differences in color are for rays vibrating parallel to certain directions which in orthorhombic crystals are $a\,b\,c$, in monoclinic crystals, one is b and in triclinic they are not related to the crystal axes.

Use mounted cubes and sections iolite 8^{26}, andalusite 8^{24}, chrysoberyl 8^{15}, epidote 5^{10}, titanite 5^{45}, axinite 2^{1}.

Absorption tufts in epidote and andalusite.

* 19. MICA COMBINATIONS. Text, pp. 161–162.

Production of uniaxial interference figure and rotation of plane of vibration by piling mica plates.

Use 5^{26}, 5^{27}, 5^{28}, 5^{29}, 5^{30}, 5^{31}.

C. THERMAL CHARACTERS.

20. CONDUCTIVITY. Text, pp. 164–165.

Illustrate surface conductivity by methods of Röntgen and de Senarmont, obtaining circular figures in isotropic or in uniaxial normal to c, but in other sections ellipses in which note relation of axes of ellipse to crystal axes.

* 21. EXPANSION. Text, pp. 166.

Indirect determination by observing effect of heat upon optical characters, especially the effect upon position of optic axes.

Sections of gypsum and glauberite.

Indirect determination by observing change in diedral angle with calcite.

D. ELECTRICAL AND MAGNETIC CHARACTERS.

* 22. MAGNETIC INDUCTION.

Suspension between poles of an electromagnet of small mass not too unequal in dimensions.

Crystals magnetically isotropic (Isometric) indifferent equilibrium for all positions.

Crystals with one axis of magnetic isotropy (tetragonal or hexagonal).

With c vertical all positions are in indifferent equilibrium.

With c horizontal it takes either axial or equatroial position.

Note + and — paramagnetic or diamagnetic character.

Crystals without any axis of magnetic isotropy (orthorhombic, monoclinic, triclinic).

Determine position and relative strengths of magnetization axes.

No experiments illustrating electrical conductivity, thermoelectric currents or dielectric induction have been devised.

23. PYROELECTRICITY.

Qualitatively by Kundt's dusting with sulphur and minium upon crystal while undergoing uniform change of temperature.

Quantitatively by self-charging electrometer.

*24. PIEZOELECTRICITY.

Qualitatively by Kundt's method, developing the strain either by unequal heating, or by direct pressure.

E. CHARACTERS DEPENDENT UPON ELASTICITY AND COHESION.

*27 ELASTIC DEFORMATION UNDER PRESSURE.

The effect of homogeneous deformation (pressure on all sides) upon the optical characters is essentially that of a uniform temperature change.

(*a*) Effect of pressure in one direction upon the optical characters.

Bending strips of glass with wire between.

Pressure of screw upon cubes.

28. PERMANENT DEFORMATION.

Cleavage, Gliding planes, Parting planes, Percussion figures, Pressure figures, Hardness. Etch figures.

DEPARTMENT OF METALLURGY.

Items: (1) SUMMER SCHOOL IN PRACTICAL METALLURGY.
(2) NEW COURSES, POST GRADUATE.
(3) DEPARTMENTAL LIBRARY.
(4) COLLECTION.
(5) FURNACE-ROOM EQUIPMENT.
(6) UNDERGRADUATE INSTRUCTION.

(1) SUMMER SCHOOL. The third year of the Summer School in Practical Metallurgy was held during the last two weeks in September. The subject of the manufacture of iron and steel was chosen for study, and the class, under direct charge of Professor Howe and Dr. Struthers, visited a large number of metallurgical works at Pittsburg, McKeesport, Latrobe, Johnstown, Steelton, Phœnixville and Pencoyd. The work of the students covered the production of cast-iron, wrought-iron and steel, and conversion into finished products.

The field selected was quite broad, and was generally discussed under the following heads:

PRODUCTION.

Blast furnace practice for cast iron, in its entirety.
Foundry practice, moulding, casting and finishing.
Puddling, fining and knobbling process for wrought-iron.
Cementation and crucible processes for steel.
Acid and basic processes for open hearth steel.
Acid Bessemer processes for steel.

MANUFACTURE INTO FINISHED PRODUCTS.

Wrought Iron, Reheating, tube drawing and rolling or hammering to merchant shapes.

Steel, Moulding and casting to special shapes, casting in ingots and subsequent treatment for plates, billets, rails, merchant shapes, etc., including reheating, forging, tire machines, rolling, cold rolling, wire drawing, tinning and galvanizing, machines for nails, bolts, etc.

The following scheme was printed and distributed to the students to help them arrange their notes. From this may be seen the thoroughness of the requirements.

COLUMBIA UNIVERSITY SCHOOL OF MINES

SUMMER SCHOOL IN PRACTICAL METALLURGY

(Third year.)

SCHEME OF STUDY.—SUBJECT: THE MANUFACTURE OF IRON AND STEEL.

BLAST FURNACE PRACTICE.

General Description.

1. Sketch outline plan of works, including furnaces, stoves, blast engine and boiler-houses, stock yard, bins and chimney.

Detailed Description.

2. BLAST FURNACE.—(State all dimensions when procurable.) Describe construction as follows: Gas take-off; down comer; dust catcher; explosion doors; charging apparatus; shaft, construction and support; mantle ring and columns; bosh, construction and support; tuyere jacket and breasts; crucible jacket; iron tap and cinder notch.

3. State the following dimensions: Height of furnace; height of stock line; height of bosh; height of inwalls; height of hearth; height of tuyeres; diameter of throat; diameter of bosh; diameter of inwalls at the bottom; diameter at tuyere; diameter at hearth; number of tuyeres; diameters of tuyeres and total cubic capacity of furnace.

4. Prepare a detailed sketch of tuyere stock and give a full description of water cooling the different parts of the furnace.

5. HOT BLAST STOVES.—Number per furnace; kind; sketch horizontal and vertical sections, giving outside dimensions of height and diameter; materials of construction; sizes of brick used and arrangement; cubic contents and square feet of heating surface; detailed sketch of gas, blast, and chimney valves.

6. NOTE.—Describe method of changing from air to gas; state the temperature to which the blast is heated at beginning and at the end of interval; state length of time between changes.

7. BLOWING ENGINES.—General description; number and kind; arrangement of air and steam cylinders; diameter of steam cylinder; length of stroke; revolutions per minute; steam pressure; diameter of air cylinder; volume and pressure of blast produced; type of valves.

8. BOILER HOUSE.—General description

9. ORE, FLUX AND FUEL SUPPLY. *General description.*—Method of transporting materials in stock yard to bins and furnaces, with detailed description of charging.

10. BLAST FURNACE WORKING. *Detailed description.*—Kind of ore; yield of ore; kind of flux and composition; kind of fuel; quantity of fuel per ton of iron; quantity of flux per ton of iron; production of furnace per 24 hours; amount, pressure and temperature of blast; rate of descent of charge; temperature of gases from the furnace top; methods of re-

moval and disposal of iron and slag and times of tapping. Number of men and kinds, fillers, trimmers, etc.; times of tapping and flushing; description and diary of a tap, breaking up pigs and making pig bed.

PUDDLING, HEATING, AND REFINING.

11. PUDDLING FURNACE. *Construction.*—Length and breadth of fireplace; dimensions of hearth, length, width at bridge, at working door and at flue; height of chimney above grate; section of chimney. 12. *Working.*—Weight of charge of iron and of puddled ball; length of time to work a charge; number of balls from one charge; coal consumed per shift per furnace; men per furnace per shift; length of shift; loss in puddling.

13. HEATING FURNACE. *Construction.*—Length and breadth of fireplace; dimensions of hearth, length, width at bridge, at working door, and at flue; height of chimney above grate. 14. *Working.*—Weight of charge; time for heating; men per furnace per shift; length of shift; coal consumed per day per furnace; loss in reheating.

15. REFINING. *Construction.*—Length, width, and depth of hearth; number, size and inclination of tuyeres. 16. *Working*—Complete diary; weight of charge; length of operation; heats per shift; number of men per shift; blast pressure; fuel consumption per furnace; loss in refining.

OPEN HEARTH STEEL.

General Description.

17. Outline sketch of plan of works, including stock yard, boiler-house, producers, furnaces, cranes and casting pit.

Detailed Description.

18. GAS PRODUCERS—Number and kind; describe construction and method of charging and working; kind of coal used and composition of resultant gas; number of producer men; length of shift.

19. FURNACE. *Construction.*—Detailed sketch showing plan, elevation and section, including hearth area; number, arrangement and area of gas and air ports; distance between ports; height of roof from hearth; charging and working doors; tap hole. Cubic capacity of regenerators and arrangement of bricks; estimated heating surface in square feet; detailed description of valves and method of reversing flame direction.

20. FURNACE. *Working.*—Capacity; composition and weight of materials charged; method of charging; control of temperature; thickness of molten metal on hearth; removal of molten products from furnace; method of recarburizing and control of the progress of the operation; repairs to hearth and lining; time of melting down, oreing, and recarburizing; tapping and repairs; percentage of loss of iron.

Complete diary of a heat; number and kind of men; time of charging materials and weights of materials in charge.

BESSEMER STEEL.

General Description.

21. Outline sketch of plan of works, including stock yard; cupolas; converters in use, drying, and repairing; blast engine and boiler-house; casting pit.

Detailed Description.

22. CONVERTER. *Construction.*—Describe materials of construction and how supported; make detailed sketch of shell and bottom, and show how held together; state thickness and composition of lining and describe method of making the bottom. 23. *Working.*—Capacity; volume and pressure of blast; depth of molten metal; detailed description of charging, blowing, pouring, recarburizing, and teeming; state the times of the different stages and corresponding flame appearance.

Complete diary of three successive charges, with description of appearance of flame and smoke to naked eye, with glasses and with spectroscope; also sound, spitting and blast pressure.

CRUCIBLE STEEL.

24. *General Description.*

Outline plan of works and briefly describe the process.

25. *Detailed Description.*

Prepare plan, elevation, and section of furnace; size and capacity of crucible; composition of materials treated and product; method of charging, operating and teeming; details of moulds; number of men; time of each stage of the operation.

PIT PRACTICE.

26. *General Description.*

Sketch plan of casting pit; briefly describe method of handling molten steel, ingots and moulds.

27. *Detailed Description.*

28. LADLE.—Sketch showing method of tapping; state materials of construction and method of operating.

29. CRANES.—General sketch.

30. SOAKING PITS.—Details of construction and operation.

31. CHARGERS AND MOULDS.—General description.

32. ROLLING.—Sketch plan of works; detailed sketch of rolls, giving type, width, pitch, diameter of rolls, outline sketch of passes; describe the method of operating; number of men; diary from bloom or ingot to finished product, including the time at which each pass is entered.

33. HAMMERS, PRESSES AND SPECIAL APPARATUS.—Such details as shall be designated.

DEPARTMENT OF METALLURGY, COLUMBIA UNIVERSITY, SCHOOL OF MINES, JULY, 1898.

The department is highly gratified with the work accomplished and the voluntary attendance of several students in other courses.

(2) NEW COURSES. Students have applied for several of the new courses in post graduate work, and the department is being especially equipped for the courses on the microscopic study of iron, steel and other metals, and for the heat treatment of iron, steel and other metals.

'3. DEPARTMENTAL LIBRARY. Through the kindness and generosity of Dr. Thomas Egleston, the efficiency of the Library has been greatly increased by the recent gift of his personal library of metallurgical books and pamphlets. This very valuable acquisition comprises more than eight hundred volumes of standard works, including the following periodicals: *Journal of the Iron and Steel Institute*, complete from 1871 to date; *Annales des Mines*, from 1832 to date; *Revue Universelle des Mines*, from 1857 to date; *School of Mines Quarterly*, complete; *Engineering and Mining Journal*, from 1872 to date; *Transactions American Society of Mechanical Engineers*, complete; *Stahl und Eisen*, complete from 1881 to date; *Berg- und Hüttenmännische Zeitung*, from 1860 to date; *Wagner's Jahresbericht der Chem. Technologie*, complete to date.

'4. COLLECTION. During the summer, many new and desirable specimens were collected, keeping in view their value for instruction purposes.

The plan adopted in arranging the material of the collection so that it can be used for lecture illustration, has proven of great aid in presenting the subject to the students.

'5. FURNACE-ROOM EQUIPMENT. The equipment of the furnace room with apparatus for illustrative and research work, which was made possible through the kindness of a friend, is now being carried on. A large furnace for uniform heat is being installed and is available for roasting ores or for high temperature work on metals. A large crucible furnace which will hold a crucible of eighty-pounds capacity is under contract.

There is a large field for research work which could be filled profitably in this room and, as the courses develope, much new material will be required.

Let us hope that some one, whether graduate of the SCHOOL OF MINES or not, will be sufficiently interested in the development of science, to help us equip this important branch of the department in a satisfactory manner.

'6. UNDERGRADUATE INSTRUCTION. This year brings into existence the new undergraduate course on iron and steel for the civil, electrical and mechanical engineers.

This course is given by Professor Howe during the second half year and consists of

3.—THE METALLURGY OF IRON AND STEEL.—Ores: Classification and constitution of iron and steel; the blast furnace; composition and properties of cast-iron; composition and properties of wrought-iron and steel, and the influence of thermal and mechanical treatment; puddling; the Bessemer, open-hearth and crucible processes, forging and rolling; casting cast-iron and steel; and the minor processes of steel and iron making. Three hours lectures a week, second half-year. J. S.

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In 1896, seventeen students from Woodbridge entered Columbia, of whom five took advanced standing, one entering the *second-year class* in Electrical Engineering. This year, 1898, fourteen of our students entered.

Four hundred Students of Columbia School of Mines have been instructed in the Woodbridge School. Also a large number have been prepared for Massachusetts Institute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Scientific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medical and Law Departments of Harvard, Yale, Columbia and Princeton.

An advanced course for older students prepares them to enter the second-year class

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THE SCHOOL OF MINES QUARTERLY.

A

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moval and disposal of iron and slag and times of tapping. Number of men and kinds, fillers, trimmers, etc.; times of tapping and flushing; description and diary of a tap, breaking up pigs and making pig bed.

PUDDLING, HEATING, AND REFINING.

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Complete diary of a heat; number and kind of men; time of charging materials and weights of materials in charge.

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SCHOOL OF MINES QUARTERLY.

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AN INTRODUCTION TO THE STUDY AND EXPERIMENTAL DETERMINATION OF THE CHARACTERS OF CRYSTALS.

BY ALFRED J. MOSES, PH.D.

(Concluded from Vol. XIX., p. 391.)

THE THERMAL CHARACTERS.

Certain substances, such as halite, are essentially transparent to both heat and light; and if sunlight be decomposed by a prism of such a substance there is obtained not only the visible color spectrum consisting of the rays between the least refracted red ($\lambda = 760.4\ \mu\mu$) and the most refracted violet ($\lambda = 393.3\ \mu\mu$), but if each ray is tested by a delicate thermo-pile the temperature will be found to increase from the violet end towards the red *and to a certain distance beyond the red* where it is maximum and thereafter to decrease, proving the existence of invisible heat rays beyond the red.

Experiments show also that these heat rays are reflected and refracted and absorbed like light rays, that they may be doubly refracted, as first shown by Knoblauch in calcite, that they may be polarized by reflection or refraction and that when polarized their power to penetrate crystals varies not only with the direction of transmission but with the direction of vibration. For instance, heat will not penetrate crossed nicols, but the interposition of a plate of

doubly-refracting substance will permit components to penetrate, except at intervals of 90° when the planes of vibration of the heat rays produced in the plate coincide with those of the nicols. Interference and circular polarization of heat rays have also been experimentally proved.

Heat rays may, therefore, be regarded as invisible light rays which are in general of greater wave-length and less refrangibility than the visible rays, but are subject to the same laws. It is possible, though difficult, to determine experimentally a series of constants for crystals with respect to these invisible rays, as in the famous experiments of Knoblauch.*

Simpler and more convenient tests can be made with respect to the conductivity or rate of transmission of heat from particle to particle, and to expansion. For both a dependence is found to exist upon the crystal structure.

HEAT CONDUCTIVITY.

The shape of the "surface of conductivity" or isothermal surface, the radii of which are the rates of conductivity in different directions, is most easily determined from the surface conductivities in sections of known orientation.

The relative surface conductivities are most satisfactorily obtained by Röntgen's modification of the older de Senarmont method. The previously cleaned and polished section is breathed upon, quickly touched by a very hot metal point normally applied, and instantly dusted with lycopodium powder. The section is then turned upside down and tapped carefully, when the powder falls from where the moisture film had been evaporated, but adheres elsewhere, giving a sharply outlined figure. The entire operation should take less than three seconds.

In all homogeneous substances in which the surface tested is large enough to allow for irregularity of contour the resultant figure is either an ellipse or a circle, that is a section of an ellipsoid.

The major and minor axes of the ellipse are carefully measured under the microscope with a micrometer eyepiece.

In the old method of de Senarmont the surface of the section is coated with a very thin layer of wax or paraffin either applied with camels' hair brush† or by melting a thin bit on the surface and

* Knoblauch, *Pogg Ann.*, LXXXV., 169; XCIII., 161.

† Tyndall, Heat as a Mode of Motion, p. 189, D. Appleton, 1891.

pouring off the excess. The wax-covered surface is placed in a horizontal position and heat applied at one point:

(*a*) By a wire or narrow tube of metal (silver, platinum, copper) passing though a hole pierced normal to the waxed surface and heated either by a lamp at some distance,* or by an electric current,† or by a current of hot air.‡

(*b*) By touching with a hot pointed wire vertically applied.

(*c*) By a little platinum ball soldered to a platinum wire, the latter being surrounded to avoid radiation and heated by an electric current.

Voigt recommends § a mixture of 3 parts elaidic acid with 1 part of wax, the mixture melting at 40° to 50° C.

A constant temperature is maintained until the coating has melted far enough from the point of application of the heat. The boundary of the melted patch is then the isothermal curve showing the distances which the heat has been transmitted, and is visible after cooling as a ridge which is always in the shape of an ellipse or circle.

As a result of the experiments it is found that:

1° In singly-refracting crystals (isometric), all sections yield circular isothermal curves; that is, the isothermal surface is a sphere.

2° In optically-uniaxial crystals (tetragonal or hexagonal) basal sections yield circular curves, but all other sections yield elliptical curves which become more eccentric as the section becomes more nearly parallel to the optic axis. That is, the isothermal surface is an ellipsoid of revolution around $\dot{c}$, the optic axis. As for light a division may be made into + and —. For instance, in quartz the conductivity is more rapid parallel $\dot{c}$ and in calcite at right angles to $\dot{c}$, hence quartz is thermally positive, calcite thermally negative.

3. In optically-biaxial crystals the isothermal curves are all ellipses and the isothermal surface is a triaxial ellipsoid, the axes of which are at right angles to each other. In orthorhombic crystals these axes coincide with the crystallographic axes, and the major and minor axes of the ellipse obtained in any principal

* de Senarmont, 1847, *Ann. de Chim. et de Phys.*, XXI., 457; XXII., 179.

† Tyndall, l. c., 190.

‡ Jannetaz, *Bull. Soc. Min.*, I., 19.

§ *Elemente der Krystallphysik*, 78.

section are parallel to the crystal axes therein. In monoclinic crystals one axis of the isothermal surface coincides with *b* and the other two lie in the plane 010. In the zone [010 100] the major and minor axes of the isothermal curves should coincide with crystal axes. In triclinic crystals there is no essential or probable parallelism of crystal axes and axes of ellipses in any section.*

EXPANSION BY HEAT.

Most† substances increase in volume when heated and contract on cooling, and experiments show that in crystals the rate of expansion is not the same for directions crystallographically unlike, but varies as follows:

1° *Isometric Crystals.* The rate of expansion is the same for all directions. A sphere heated becomes a sphere of larger diameter.

2° *Tetragonal and Hexagonal Crystals.* The rate of expansion is the same for all directions equally inclined to the axis *c*; is either a maximum or a minimum parallel to *c*, and varies regularly from this to the direction at right angles. A sphere heated becomes an ellipsoid of revolution around *c* as an axis.

3° *Orthorhombic, Monoclinic and Triclinic Crystals.* There is no axis of isotropy. The directions of maximum and minimum expansion are at right angles, and a sphere heated becomes a triaxial ellipsoid, the axes being these directions and a third at right angles to their plane.

Orthorhombic, the axes coincide with the crystal axes.

Monoclinic, one axis coincides with *b*, the others lie in 010, but not coincident with conductivity axes or principal vibration directions.

Triclinic, the axes have no fixed positions relative to the crystal axes.

* Jannetaz showed an apparent connection between directions of cleavage and ease of conductivity. For instance, the isothermal surface for uniaxial crystals which have an easy basal cleavage is usually a flat oblate spheroid. If the direction of cleavage is not basal, but oblique, the longer axis will often be in the section most nearly parallel to the cleavage. As will be later explained, planes of cleavage are supposed to be directions of greatest closeness of molecules, and it seems, therefore, that the rapidity of transmission increases as the molecules are closer together. It is curious, however, that if an amorphous substance, such as glass, is subjected to compression or tension the isothermal circles become elliptical, the shorter axis being in the line of greater pressure or packing of molecules.

†A few expand on cooling below a certain point and one, at least, iodide of silver, contracts when heated above the ordinary room temperatures.

DIRECT MEASUREMENT OF LINEAR EXPANSION.

The coefficient of linear expansion, that is the increase in a unit of length for a temperature change from 0° to 1° C. may be accurately measured for any direction by the method of Fizeau * which as perfected by Abbe is as follows: †

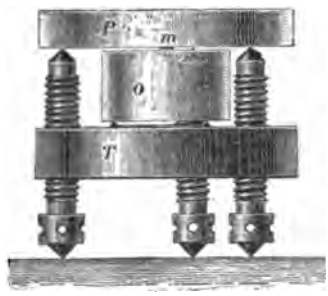

FIG. 282.

In Fig. 282 *O* is a plane parallel plate of the crystal, about 10 mm. thick, which rests upon three projections turned upon the steel plate *T*. Three screws, with a fine 2 mm. thread, pass through *T* and support the glass plate *P*, which tapers slightly so that when the upper surface is horizontal the lower is inclined about 20 minutes. By adjusting the screws a thin wedge-like film of air is left between the horizontal polished surface of the substance and the lower surface of the glass.

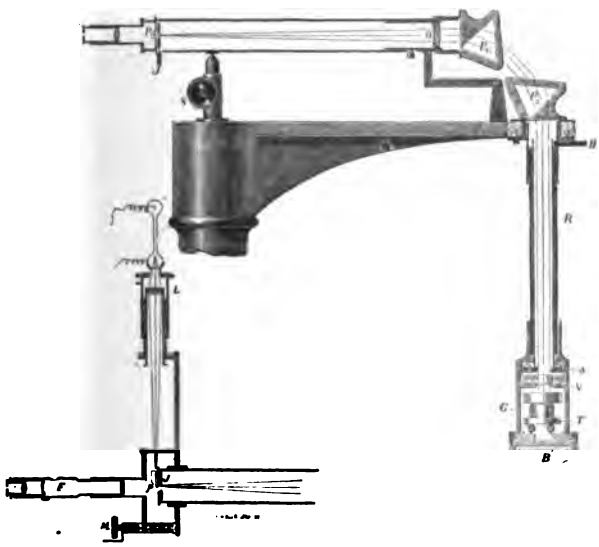

FIG. 283.

The telescope *PO*, Fig. 283, is at once telescope and collimator, that is the light from a Geissler tube, shown at *L* in the smaller

* Description by J. R. Benoit, *Trans. et Mem. du bur. internat. des poids et mes.*, I., 1, 1881; VI., 1. 1888.

† Described by C. Pulfrich, *Zeit. f. Instrumentkunde*, XIII., 365, 401, 437.

figure, enters at the side, is deflected by the prism P, made parallel by the lens system O, decomposed by the two flint glass prisms P_1 and P_2 and by varying the angles at which these are set by the screw S, rays of any chosen color are made to pass vertically through R and reach the interference apparatus within the brass vessel G.

The rays incident at the upper surface of the crystal plate and the lower surface of the glass plate interfere on reflection producing parallel dark bands wherever the thickness of the air film is $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, etc. The distance between two adjacent bands is therefore a function of the wave-length of the light used. This distance is measured by a screw micrometer M which moves a vertical double hair horizontally across the field.

The vessel G containing the interference apparatus is enclosed in two concentric cylinders, the outer one containing a liquid. When the liquid is heated the crystal plate and the interference apparatus both expand and the interference bands change in distance apart. From this change and from the previously determined effect of the expansion of the apparatus the change due to the expansion of the crystal is calculated.*

Voigt describes† a simpler apparatus in which the expansion of the crystal tips one of two parallel mirrors. Reflected signals from the two mirrors are viewed by a telescope one meter distance and their divergence measured. The apparatus is heated by immersion in paraffin oil at 60° to 70° C.

MEASUREMENT OF EXPANSION BY CHANGE IN DIEDRAL ANGLES.

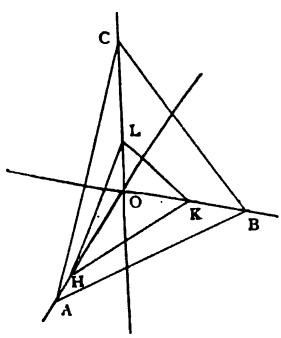

FIG. 284.

The indices and therefore the zone relations are not changed by uniformly heating a crystal, for any series of points on a straight line remains on a straight line and at the same proportionate distances apart. If, therefore, in Fig. 284 ABC is the unit plane and HKL any other plane, the points O, K and B will after expansion be on a straight line and the same proportionate distance apart, so also O, L and C or O, H and A. Therefore, the indices of HKL after expansion will be

* *Zeit. f. Instk.*, XIII., 440, etc.
† *Wied. Ann.*, XLIII., 831, 1891.

$$\frac{OA'}{OH'} = \frac{OA}{OH} = h, \quad \frac{OK'}{OB'} = \frac{OK}{OB} = k; \quad \frac{OL'}{OC'} = \frac{OL}{OC} = l; \text{ or } hkl.$$

In *isometric crystals* the angles are unchanged by expansion, but in all other systems all diedral angles are altered except that:

(*a*) Faces parallel to two expansion axes remain parallel to their original position and normal to all faces in the zone of the third axis.

(*b*) If the rates of expansion are equal parallel to two axes the faces in the zone of the third axis remain parallel to their original positions.

In *tetragonal and hexagonal crystals* by (*a*) the basal planes remain at 90° to the faces in the prismatic zone, so also any face in the prism zone remains at 90° to all faces of the zone originally normal to it and by (*b*) all angles in the prismatic zone remain constant.

In *orthorhombic* crystals since *a*, *b* and *c* are expansion axes, each pinacoid remains at 90° to every face in the zone of the third axis.

In monoclinic crystals the clino pinacoid remains at 90° to faces in the zone of *b*.

From the change in angle the linear coefficients may be calculated.*

The change in angle is usually small, requiring delicate measurement. It may be demonstrated† by cutting a plate-like cleavage of calcite, Fig. 285 *a*, normally and parallel to the longer diagonal of the larger face, reversing one-half and gluing as in *b* with water glass. On heating, the adjacent angles expand in the same direction and, as exaggerated in *c*, one-half becomes inclined to the other about 20′ for 100° C. temperature change. This bending is easily shown by reflection of a signal on a screen 3 meters distant.

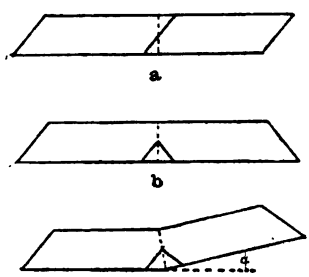

FIG. 285.

* For instance if the rhombohedral angle of a calcite cleavage, which decreases almost 9′ for 100° elevation, is 105° 5′ at 10° C. and 104° 56′ at 110° C. then by formulæ, $\sin a = \cos \frac{1}{2} X \times 1.155$, $\tan a \times .866 = c$, (Moses' and Parson's Mineralogy, p. 60) we have $l \sin a = 9.84663$, $a = 44°.63$, $\tan a \times .866 = c = .8549$, and $l \sin a' = 9.84732$, $a' = 44° 72$ $\tan a \times .866 = c' = .8575$.

† Voigt, Elemente der Krystalphysik, p. 49.

Determination of Expansion by Changes in the Optical Phenomena.

The expansion of a crystal produces a change in the rapidity of transmission of light which may be determined by measurement of the indices of refraction or indirectly by the interference phenomena.

In *singly refracting* (isometric) crystals the change is alike in all directions. The crystal remains optically isotropic but the index of refraction may become smaller as with fluorite, or larger, as with diamond.

In *uniaxial* (tetragonal and hexagonal) crystals the changes in velocity are unequal, that is the principal indices of refraction γ and α vary unequally and not necessarily in the same direction.* The strength of the double refraction $\gamma - \alpha$ may be either increased, raising the interference color and contracting the rings in the interference figure, or the reverse may take place. The change when $\gamma - \alpha$ is made less may, for a certain temperature, reduce the double refraction to zero, that is *for that color of light and at that temperature* the crystal is optically isotropic and for a further temperature change in the same direction will change in optical character from + to − or − to +.

In *biaxial* crystals (orthorhombic, monoclinic and triclinic) the unequal changes in α β γ, the principal indices of refraction, are indicated not only by raising or lowering the interference colors and in the contraction or expansion of the rings of the interference figure but by changes in the angle between the optic axes, which is simply a function of the principal indices. If either α or γ at any temperature become equal to β then for that temperature and light the crystal is uniaxial and the axial angle is zero and for a further change in the same direction the former middle index β will become α or γ, that is $\mathfrak{b}$ will become $\mathfrak{a}$ or $\mathfrak{c}$ and the optic axes will pass into a plane at right angles to the former position of the axial plane. Fig. 286 represents successive changes in such a transformation.

Fig. 286.

* With increased temperature:

	α	γ	$\gamma - \alpha$
Calcite	increased	increased	increased
Beryl	increased	increased	decreased
quartz	decreased	decreased	decreased

The following selected examples illustrate these facts.

BARITE (Orthorhombic). $2E$ for sodium flame *increases* with rising temperature from 64° 1′ at 20° C. to 68° 51′ at 100° C. and 77° 16′ at 200° C.

GLAUBERITE (Monoclinic). The principal vibration directions are essentially unchanged, but $2E$ *decreases* with rising temperature. Within a range of 40° C. the crystals become successively uniaxial for all colors and the axes thereafter are in a plane at right angles to the former axial plane.

Temperature	Apparent Angle $2E$ for			
Centigrade.	Li Red.	Na Yellow.	Tl Green.	Blue.
18°	———	———	———	0°
22°	13° 30′	11° 8′	8° 14′	———
36°	11° · 1′	8° 9′	0°	8° 42′
46°	8° 40′	0°	7° 8′	11° 8′
58°	0°	7° 14′	10° 32′	13° 2

GYPSUM (Monoclinic). The angle $2E$ decreases with rising temperature and the principal vibration directions change, the dispersion changing from inclined to horizontal.

Temperature.	$2E$ for	Temperature	$2E$ for
Centigrade.	Na Yellow.	Centigrade.	Li Red.
20°	92°	20°	96°
50°	79°	47°	76°
100°	51°	71°	59°
116°	36°	95°	39°
134°	0°	116°	0°

The test is usually made by replacing the glass vessel *M*, Fig. 273, by a metal air bath, Fig. 287, consisting of a rectangular hol-

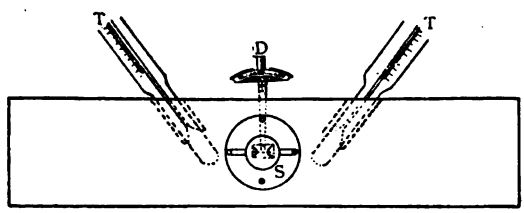

FIG. 287.

low box of copper, which projects on either side beyond the polariscope, and is heated by gas burners. At the top is an opening for the crystal carrier, and at the large sides are glass windows so set in tubes, that by a key the distance apart can be made as small as the crystals will permit. From the top of the box project two thermometers *T* reading to 300° C.

The crystal section is adjusted, and the angle is determined at room temperature, the two burners are then lighted and the heating continued until a constant temperature can be maintained for one-half hour, when a new reading is made; this is repeated for different intensities of flame.

THE MAGNETIC INDUCTION OF CRYSTALS.

All substances are either attracted or repelled in some degree when in the field of a strong electromagnet. If attracted they are said to be "*paramagnetic*" or "*magnetic*;" if repelled they are "*diamagnetic*."

If a rod of any substance is suspended by a fibre so as to swing freely horizontally between the vertical poles of an electromagnet, *ab*, Fig. 288, magnetic induction takes place and as the lines of force between the poles are essentially horizontal, the effect of the pull or thrust upon rotation is greatest for the particles furthest from the axis of rotation. If paramagnetic, therefore, the effect is to pull the rod into a longitudinal or "*axial*" position with its ends as near the poles of the magnet as possible, and if diamagnetic the rod is pushed into a transverse or "*equatorial*" position with its ends as far from the magnetic poles as possible.

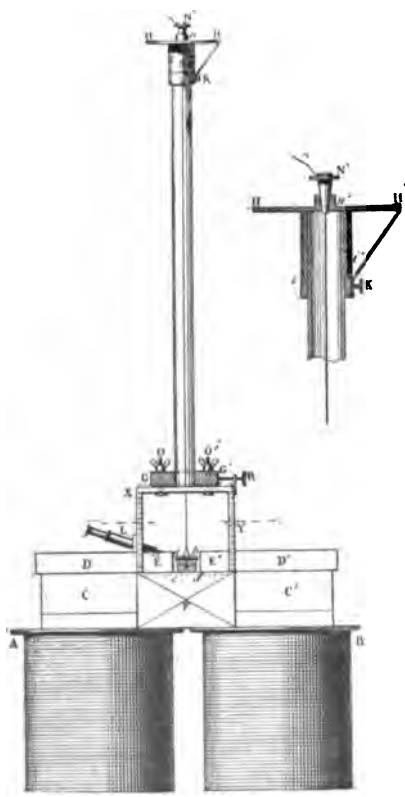

FIG. 288. $\frac{1}{10}$ natural size.

Fig. 288 shows the apparatus of Edmond Becquerel* in which *A* and *B* are the poles of a large electro-magnet, *C* and *C'* square soft iron pole pieces and *DE*, *D'E'* long narrow soft iron pole pieces placed so that

* *Ann. de Chim. et de Phys.*, 1850, V., 28, p. 283.

the back face of $D\,E$ and front face of $D'\,E'$ lie in the same plane through the torsion thread. Bars of 25 mm. long, 2 to 5 mm., broad are suspended in the position $a\,b$ and adjusted by the torsion head N until a scratch at one end of the bar coincides with the cross hair of the telescope L. The current is then turned on and the deviation due to attraction or repulsion observed and measured by the amount it is necessary to turn the circle $H\,H'$ to restore the original position.

With crystals, however, the particles in certain directions become more strongly magnetized than in others, and the para- or diamagnetism is judged by hanging a thin glass tube, filled with powder of the substance, between the magnetic poles, the particles of the powder having all possible orientations all effect of direction is eliminated.

To Determine the Relative Strength of Magnetization in Different Directions in a Crystal.

The crystal is suspended by a silk fibre and should be of such a shape that the section normal to the axis of suspension is circular. If, however, the crystal is small, the form is less important.

Plücker used for his experiments a large electromagnet with six Groves elements, the poles of the magnet being 1.6 inches apart and the space around the poles protected from currents of air by a glass cage. The crystal was suspended by a double silk thread from a torsion balance.

The direction, in the section normal to the axis of suspension, which is most strongly affected will evidently take an *axial* position with paramagnetic crystals and an *equatorial* position with diamagnetic crystals.

By suspending a cube by its three rectangular axes, a, b and c, successively the magnetic intensities in these directions may be compared, for instance:

Axis of rotation	a	b	c
Axial direction assumed by	b	a	b
Equatorial direction assumed by	c	c	a

If the crystal is diamagnetic, then, since c was twice equatorial, c is the axis of greatest magnetization, but if paramagnetic, then is b the axis of greatest magnetization.

The relations cannot yet be said to be well understood as very

few minerals have been thoroughly tested. It does not appear that isometric crystals are magnetically isotropic, for the latest investigations of magnetite show that prisms cut parallel to a ternary axis are most strongly magnetized, those parallel to a binary axis only a little more feebly and those parallel to a quaternary axis much more feebly.*

The experiments of Plücker † appear to prove that all crystals of other systems are magnetically anisotropic and that a suspended sphere in a uniform magnetic field is in stable equilibrium only when the direction most strongly magnetized is "axial," that is, is parallel to the lines of force.

In hexagonal and tetragonal crystals the direction of maximum magnetization is either parallel or at right angles to the vertical axis c and the crystal is said to be magnetically positive or magnetically negative. If a sphere is suspended with c horizontal then four cases ‡ result.

Paramagnetic positive, the position of c is axial.

Paramagnetic negative, the position of $\dot{c}$ is equatorial.

Diamagnetic positive, the position of $\dot{c}$ is equatorial.

Diamagnetic negative, the position of c is axial.

In orthorhombic, monoclinic and triclinic crystals the directions of maximum and minimum intensity, are at right angles to each other and the intensity of the third axis of the "induction ellipsoid" is at right angles to their plane.

In orthorhombic crystals § these axes are the crystal axes a, b, c. In monoclinic crystal one axis is parallel to b, the others are in 010, but not necessarily or probably parallel either to axes of

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* Aimantation non isotrope de la Magnétite cristallisée.—P. Weiss.—*C. R.*, CXXII. 1405.

† *Pogg. Ann.*, v. 72, p. 315; v. 76, p. 576; v. 77, p. 447; v. 78, p. 427; v. 86, p. 1.

‡ Examples are:

+Paramagnetic,	—Paramagnetic,	+Diamagnetic,	—Diamagnetic,
Siderite,	Tourmaline,	Calcite,	Bismuth,
Wernerite,	Beryl,	Mimetite,	Arsenic,
Torbernite,	Vesuvianite,	Wulfenite,	Zircon.

§ Examples are:

		Strength of Magnetization.		
		$\phi_1 >$	$\phi_2 >$	ϕ_3
Topaz,	Paramagnetic,	a	c	b
Anhydrite,	Diamagnetic,	a	b	c
Barite,	Diamagnetic,	c	a	b
Epsomite,	Diamagnetic,	c	b	a

thermal conductivity or optical principal vibration directions. In triclinic crystals there are no fixed relations.

Practically no satisfactory determinations have been made of absolute values of coefficients.

ELECTRICAL CHARACTERS.

TRANSMISSION OF ELECTRIC RAYS. *

Electric waves differ from light waves only in their vastly greater length, they travel with the same velocity and exhibit similar phenomena. Many substances opaque to light waves are transparent to electric waves, and in this lies the hope of a series of tests for optically opaque crystals corresponding to the series for optically transparent crystals.

Professor Bose † describes an apparatus, essentially an electric polariscope, the polarizer and analyzer consisting of wire gratings, made by winding fine copper wire 2 mm. diameter around a thin sheet of mica (about 25 lines per cm.); the mica pieces are then [illegible]n melted paraffine, after which a round disc is cut from the sheet. The electric waves are produced by a small Ruhmkorff coil causing oscillatory discharges between two small (1½ cm.) metallic spheres; beyond these the same tube is a convex lens with a spark gap at its principal focus, then follow in order the grating polarizer, the crystal, the grating analyzer, a modified coherer, and a connected, distant d'Arsonval galvanometer.

When the gratings are crossed no current is shown, the introduction of the crystal produces a current which is shown by the throw of the needle reflected by a mirror upon a scale. When the principal vibration directions of the crystal coincide with those of the gratings no current passes. Crystals of moderate size are successfully tested by this apparatus.

ELECTRICAL CONDUCTIVITY.

Electrical conductivity, although varying between very wide limits in different substances,† appears to be dependent much more

* The Polarization of Electric Rays by doubly refracting Crystals.—J. C. Bose, *Jour. Asiatic Soc.*, Bengal, LXIV., 291, 1895.

† No substance possesses absolute electrical resistance; practically, however, conductivity may be considered to be limited to the metals; some metalloids; most sulphides, tellurides, selenides, bismuthides, arsenides and antimonides, some of the oxides; and, at higher temperature, a few haloids.

upon the constitution of the chemical molecule than upon the crystalline structure. A certain dependence upon crystallographic direction has, nevertheless, been observed in a few substances.

The principal experiments are those of Wortman,* and the more recent series by Beijerinck.† Both used essentially the same method, in which a prism of known dimensions was introduced into a direct weak current, the strength of which was varied by resistances and the deviation observed in a galvanometer.

Good contact was obtained by using tough copper amalgam or sometimes bright sheet lead or simply graphite rubbed on with a lead pencil. Natural faces were cleaned with acid, caustic soda, water and alcohol, and sometimes even with hydrofluoric acid.

To study the effect of temperature the substance was heated in a small air bath made with double walls of asbestos and covered with copper, thus giving a very regular distribution of temperature without thermo-electric effects.

The principal results bearing upon crystal structure are as follows:

Isometric Crystals.

Magnetite, the electrical conductivity is essentially alike in all directions.

Tetragonal and Hexagonal Crystals.

Hematite,‡ hexagonal, the electrical conductivity parallel to c is essentially twice that normal to c and for any direction making the angle α with c; the resistance is $\omega = \omega_a \sin^2\alpha + \omega_c \cos^2\alpha$ in which and ω_a are the resistances parallel and normal to c.

Cassiterite, tetragonal, and zincite, hexagonal, give conformable results.

Orthorhombic Crystals.

Marcasite and bismuthinite, show the greatest and least resistances parallel to two of the axes a, b, c.

That is, the few tests recorded show that the electrical conductivity of crystals conforms to the thermal conductivity.

THERMOELECTRIC CURRENTS.

If a metallic circuit is made by soldering together one end of each of two rods of different metals and connecting the other ends

* Mem. de la Soc. d. hist. Nat. de Genève, XIII., 1853.

† Ueber das Leitungsvermögen der Mineralien für Elektricität.—F. Beijerinck.—*Neues Jahrb. Min.*, Beil. Bd., XI., 403, 1896–7.

‡ H. Bäckström.—*Öfv. d. K. Vetenskaps-Ak. Förh.*, 1894, No. 10, 545.

by wire, heating or cooling the junction will develop an electric current the strength of which will depend upon the change of temperature and upon the metals used.

In a crystal the electromotive force of the current in part depends upon the crystallographic direction, and a thermoelectric current may be produced:

(*a*) By coupling rods cut in different directions from the same crystal and heating the junction.

(*b*) By inserting a rectangular parallelpipedon longitudinally in a metallic circuit the sides being kept at a constant equal temperature but the ends differing. For example, Bäckström* placed hematite between two sheet-copper boxes, through one of which water was flowing and through the other steam. The boxes were connected by wires with a Lippman capillary electrometer.

(*c*) The end surfaces may be held at the same temperature† and two opposite side faces at different temperatures.

Friedel‡ clamped three plane parallel plates between two platinum wires, touching equal spaces on the crystal, connected the plates with a galvanometer and placed them in a space uniformly heated by a water bath.

Slight impurities appear to produce very notable changes in the thermoelectric results.

DIELECTRIC INDUCTION IN CRYSTALS.

A crystal suspended in an electrostatic field develops in an almost inconceivably short period§ an electric polarity, and the crystal tends to assume a position in which the lines of force and the direction of maximum induction are parallel.

According to the experiments of Root‖ the directions of maximum and minimum induction are respectively the principal vibration directions c and a in light transmission. In these experiments circular plates of tourmaline, quartz, and calcite, about 10–11 mm. in diameter and cut parallel to the optic axis, were attached by a little drop of glue to a silk thread and suspended between the vertical plates of a condenser charged by a rapidly alternating

* Last cit.

† Liebisch, *Grundriss der Phys. Kryst.*, 217.

‡ *Ann. de Chim. et de Phys.*, 1869, XVII., 79.

§ Less than 0.0000821 second, according to Root.

‖ *Poggendorf's Annalen*, CLVIII., 1, 425, 1876.

current. The vibration through an arc of 10–20 minutes thereby produced in the plate was reflected to a telescope two meters distant, and its period determined both when the direction of maximum induction was vertical and when horizontal. The quotient of the former by the latter gave a basis of comparison. Aragonite and topaz were also tested. For instance,

	Period of vibration when direction of maximum induction is		Quotient of $\frac{A}{B}$
	A. Vertical.	*B*. Horizontal.	
Aragonite	4.1125	3.768	1.091
"	4.0500	3.668	1.105
Calcite	2.240	2.175	1.022

The condenser Fig. 289 consisted of a ring *C* of gutta percha serving as a frame for the two vertical brass plates *A* and *B*. Through *C* passed the glass tube *D* with a torsion head to which the discs were hung between *A* and *B* by a single thread of silk. The motions of the disc were observed through the opposite glass windows *E*. A voltaic current passing through a commutator produced alternately + and — charges in *A* and *B* in some instances as rapidly as 6,000 alternations per second.

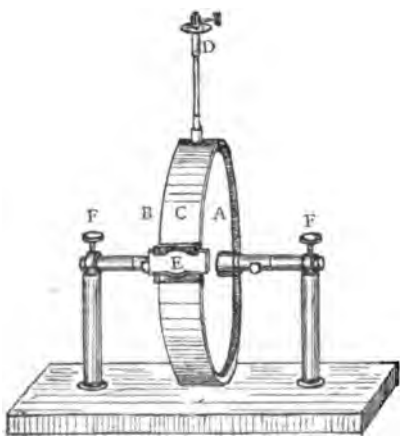

FIG. 289.

As all dielectrics have some degree of conductivity the electric polarity is apt to be modified by the more slowly developed conductivity phenomena.

The effect of conductivity in use of the constant current was shown by suspending a calcite plate with *c* horizontal. *c* was at first axial but in less than two minutes turned reversing the poles, whereas with alternating current *c* was equatorial.

The strength of the induction in any direction is indicated by the so-called dielectric constant* which may be determined by

* Maxwell assumes to be proportionate to the square of the constant *A* in Cauchy's formula for dispersion, $n = A + \frac{B}{\lambda^2}$ or, since if $\lambda = \infty$ $n = A$, to the square of the index of refraction for light of infinite wave-length vibrating parallel the given direction. (Groth, *Phys. Kryst.*, III. Ed., 194.)

the method of Bolzmann * in which the attractions exerted are measured as follows: A small sphere of the dielectric to be tested is attracted by a fixed charged metal sphere and the amount of its deviation h determined by the deflection of a mirror; the sphere is then replaced by another sphere of the same diameter but coated with tin foil and the deviation h' of this produced by the same charge in the metal sphere is determined; then, according to Bolzmann, if ε is the dielectric constant

$$\varepsilon = \frac{\frac{h'}{h} + 2}{\frac{h'}{h} - 1}.$$

either for uniaxial crystals or for biaxial crystals in which an axis of dielectric symmetry is parallel to the lines of force.

The constants may also be determined by comparison of capacity.†

From the dielectric constants in the principal directions the constants for any direction may be calculated.‡

If $D_a D_b D_c$ are the principal constants the constant D_r for any direction is:

$$D_a \cos^2(a.r) + D \cos^2(b\,r) \perp D_c \cos^2(c\text{-}r)$$

The conductivity on the plane surface of a dielectric crystal theoretically must conform to the dielectric constants in different directions.

Wiedemann's§ Experiment.—An insulated needle was fastened in proper holder in normal contact to a crystal face, previously covered with a poorly conducting powder such as lycopodium or minium, and positively charged by contact with the knob of a leyden jar. The powder near the point is tossed aside in shapes which are elliptical or circular according to surface. The results can be made permanent by collodion. In general the longest axis is in the vibration direction of the light of greatest velocity.

de Senarmont's|| Experiments.—de Senarmont coated the crystal with tin foil except that a circular hole was cut in the foil covering the face to be studied. The foil was grounded the crystal was placed in partial vacuum opposite a point of brass wire from which *positive* electricity was discharged following a direction assumed therefore to be that of easiest conductivity. The tests are made in the dark.

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* *Ber. Ak. Wien.* (2), LXX., 342, 1874, also Ch. Borel, *Arch. Soc. Phys. et nat. de Genève* (3), XXX., 131, 1893.

† Liebisch, *Grundriss der Phys. Kryst.*, 230.

‡ A. Lampa, *Ber. Ak. Wein.*, CIV., 1179.

§ *Pogg. Ann.*, 76, 404, 1849.

|| de Senarmont, *Ann. de Çhim. et de Phys.* (3), 28, 257, 1850.

PYRO-ELECTRICITY.

Equal positive and negative charges of electricity are developed at different points or poles of certain crystals during a uniform change of temperature.

A temperature change of at least 70° to 80° C. is desirable. Usually the crystal is heated in an air bath to a uniform temperature, then drawn quickly once or twice through an alcohol flame to remove any electricity occurring on the surface, and then brought into a cooler place and allowed to cool.

If heating injures the crystal it may be cooled from the room temperature by a freezing mixture.*

During the cooling of the crystal the positive charges collect at the so-called *antilogue* poles, and the negative charges at the *analogue* poles,† and may be distinguished by their effect on other electrified bodies. For instance, a cat's hair rubbed between the fingers becomes positively electrified and is attracted by the analogous pole and repelled by the antilogous pole, or as in the method of Hankel,‡ the poles may be touched by a platinum wire carefully insulated and worked by a system of levers, and the charge conducted to an especially constructed gold leaf electrometer.

Kundt's§ method is, however, most generally employed and consists in blowing upon the cooling crystal a fine well dried‖ mixture of equal parts of powdered sulphur and red oxide of lead. The nozzle of the bellows is covered by a muslin net and, in passing through, the sulphur is negatively electrified and is attracted by the positive poles coloring them yellow, while the minium is positively electrified and is caught by the negative poles coloring them red. By pressing the crystal upon sticky paper a permanent record can be obtained. The dust should fall evenly and the bellows be held far enough away to prevent direct action of the blast.

The figures here shown¶ represent crystals dusted with sulphur and minium during cooling, the darker dotted portions showing the analogue poles, the hatched portions, the antilogue poles.

* Snow or ground ice and salt; 3 pts. snow or ground ice with 1 pt. H_2SO_4; 2 pts, snow or ground ice with 3 pts. crystals $CaCl_2$.

† With rising temperature these are reversed.

‡ G. W. Hankel, Inaug. Dissertation.

§ *Pogg. Ann.*, CXXXVI., 612, 1862; *Weid. Ann.*, XX., 592, 1883; XXV., 145. 1886.

‖ Dry over H_2SO_4 in a vessel from which the air has been partially exhausted.

¶ Drawn from the colored plate III. in Groth, *Phys. Kryst.*, III. ed.

Fig. 290 represents a tourmaline crystal, Fig. 291 a calamine crystal, in both of which polarity is shown with reference to the

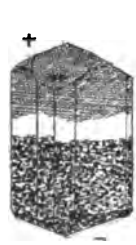

FIG. 290.

FIG. 291.

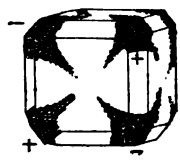

FIG. 292.

vertical axis. Fig. 292 represents a boracite crystal, showing polarity with reference to four axes, and Fig. 293 a quartz crystal with three axes of polarity. Fig. 294 shows a basal section of quartz.

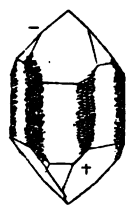

FIG. 293.

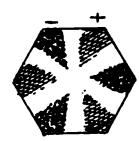

FIG. 294.

FIG. 295.

Quantitative examinations were made by Gaugain * by coating the ends of a cylinder of the crystal with tin foil, connecting one end to the ground and the other to some form of self-discharging electroscope. The number of discharges are counted and serve as a relative measure especially if the capacity of the electroscope is small. In this way it was shown that with tourmaline the amount is independent of the time of cooling, is alike for the same change of temperature in either direction, and is independent of the length, but proportionate to the cross section and to the difference between the end temperatures.

THEORY OF LORD KELVIN.

Lord Kelvin theorized † that tourmaline, in which pyroelectricity was first observed, is internally in a state of uniform electric polarity, and that, therefore, at the surface there should be an

* *Ann. de Chim. et de Phys.*, III., 57.

† Math. phys. papers Sir. William Thomson, I., 315.

electric charge of uniform surface density. In a medium not perfectly insulating such as damp air there is gradually formed by induction an electric layer completely neutralizing the charge in the tourmaline, that is making it essentially non-electric.

But if the tourmaline is heated or cooled the strength of the internal polarization is altered, while that of the electrified layer of outer medium is more slowly altered and the effect is electric polarity.

Riecke * confirmed this theory by showing that, in a fairly perfectly insulating medium, tourmaline remained electrified twenty to thirty hours, *after cooling* to its normal temperature. The heated tourmaline while still non-electrified was placed under an air pump over a gold leaf electroscope and the air slightly rarefied.

PIEZO-ELECTRICITY.

Electric charges may be developed by pressure, for instance, calcite pressed between the fingers becomes positively electrified, tourmaline compressed in the direction of c shows a positive charge at the antilogue end and a negative charge at the analogue end or precisely the charge which would result from cooling; whereas, if the pressure is removed and the crystal allowed to expand the charges are reversed conforming to rising temperature. The quantity developed is always proportionate to the pressure.

If strains are developed by unequal heating electrical charges may be developed as, for instance, by standing a basal section of quartz upon a hot centrally placed metal cylinder, the distribution of charges conforming to the effect of cooling a complete crystal, whereas, with a hot metal ring the charges are reversed.

The methods for detecting the charges are the same as for pyroelectricity. Fig. 295 shows the distribution of the charges in a basal section of quartz produced by pressure in the direction of the arrows which conforms evidently to Fig. 294, or the effect of cooling.

For quantitative examination J. and P. Curie used the following method.†

The crystal is cut in the form of a rectangular parallelopipedon, Fig. 296, and two opposite faces, A, B, covered with tin foil. One of these, A, is grounded; the other, B, is connected with one of the plates of a condenser C of known capacity, and also with one

* E. Riecke, *Wied. Ann. 28*, 43, *31*, 889, *40*, 264, *49*, 421.

† Compte Rendu, XCI., 294, 383; XCII., 350.

of the couples SS of a Thomson-Mascart electrometer. The other plate of the condenser is grounded, and the couple $S'S'$ of the electrometer is connected with one pole of a Daniell cell, the other pole being grounded.

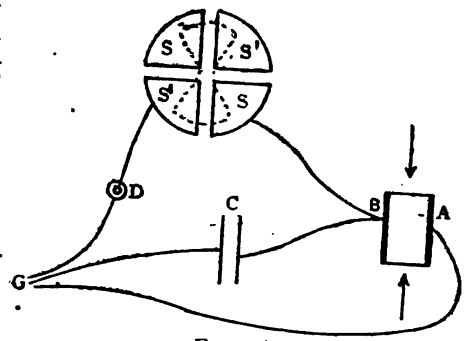

FIG. 296.

The relation between the pressure employed and the electricity developed is determined as follows: Let D denote the potential of the Daniell cell, C the capacity of the condenser, and c the capacity of the system, consisting of the plate B, the couple SS and the conductors.

For some pressure P, in the direction of the arrows, the needle of the electrometer will be at zero and the entire system charged to a potential D. That is, the pressure will have developed* a quantity $Q = (C + c)D$.

If the condenser is removed the pressure necessary to bring the needle again to the zero position will be P', and the quantity developed will be $Q' = cD$, hence for the pressure $P - P'$ the quantity developed is $Q - Q' = CD$, that is a quantity sufficient to charge a condenser of known capacity C to a known potential D.

THEORY OF PYRO- AND PIEZO-ELECTRICITY.†

Whenever the volume of a crystal is altered either by a temperature change or by mechanical pressure a portion of the heat energy or mechanical energy may be converted into electric energy, which, in poorly conducting crystals, will frequently be manifested by the accumulation of positive and negative charges at different points or poles.

Conversely, as shown by Lippmann,‡ a section which becomes for instance, positively electric by normal pressure must, if charged with positive electricity, *expand* in the direction of the normal. In other words, the electric charges are functions of the change in volume.

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* Quantity equals capacity times potential.

† W. Voigt, *Wied. Ann.*, LV., 701, 1895.

‡ G. Lippman, *Ann. Chim. et Phys.*, (5) XXIV, 145.

J. and P. Curie devised* a delicate apparatus for measuring the force of such expansions and the measured results for quartz, checked almost absolutely with the calculated results.

Crystals symmetrical to a central point (Groups 2, 5, 8, 13, 15, 21, 22, 25, 27, 29, 30, 32) cannot develop opposite charges at the ends of a diameter. The apparent exceptions obtained by Hankel and others have not all been explained, but may in part be due to influences dependent on the method of conducting the operation, in other cases, barite, for instance, they have been ascribed† to twin structure.

EFFECT OF ELECTROSTATIC FIELD UPON OPTICAL CHARACTERS.

Kundt‡ coated two of the sides, parallel *c*, of a quartz parallelopiped, with tin foil, connected these with the electrodes of a Holz machine and found that the circular interference rings became elliptical, the minor axes of the ellipses being parallel to the direction of expansion produced by the charge. Pockels§ shows that the change is too great to be simply a consequence of the expansion and must be in part due to a direct influence of the electric force on the light motions.

ELASTIC DEFORMATION.

In an elastic substance the distance apart and relative position of the particles may be changed by mechanical force, and up to a certain so-called "elastic limit" the particles will, on removal of the force, regain their former position. Such a change is called an elastic deformation or form-alteration.

HOMOGENEOUS ELASTIC DEFORMATION.

The only recorded experiments by pressure on all sides were made upon halite by aid of a piezometer.‖ The cubic compression coefficients have, however, been calculated by Voigt for a number of species. The same five classes result as with the homogeneous deformation produced by changes of temperature.

The alteration produced by a change of temperature cannot be exactly compensated by uniform pressure on all sides except in the case of isometric crystals.¶

* Brief description Liebisch, *Grundriss der Phys. Kryst.*, 481.

† Beckenkamp, *Zeit. f. Kryst.*, XXVII., 85.

‡ *Wied. Ann.*, XVIII., 228, 1893.

§ F. Pockels, *Abh. d. k. Ges. a. Göttingen*, XXXIX., 1–204.

‖ Röntgen and Schneider, *Wied. Ann.*, XXXI., 1000, 1887.

¶ Liebisch, *Phys. Kryst.*, 1891, 576.

ELASTIC DEFORMATION DUE TO PRESSURE IN ONE DIRECTION.

Observation shows that the extension or compression of any rod of length l, breadth b and thickness t, produced by a weight W acting in the direction of the length, is $\frac{Wl}{bt} E$, in which E is a characteristic factor called the coefficient of extension. Obviously if W, l, b and t are unity, the extension becomes equal E, that is the coefficient of extension is the extension produced upon a unit rod by a unit weight.

The most convenient method of obtaining the extension coefficient for any direction in a crystal is by cutting a thin rod R, Fig. 297, of rectangular cross section, in the given direction, supporting it, as shown, upon the two rests A and B, and loading by a weight W connected with a centrally placed knife edge. The deflection of the central section produced by the weight is determined by Koch as follows:* A rectangular glass prism P is placed just below and with one face parallel to the rod, and another face vertical. Monochromatic light is reflected upon the hypothenuse face, and, very much as in the Fizeau apparatus, p. 111, interference bands are produced by the rays reflected from the lower surface of the rod R and the upper surface of the prism P, and are viewed by a horizontal telescope through the vertical face.

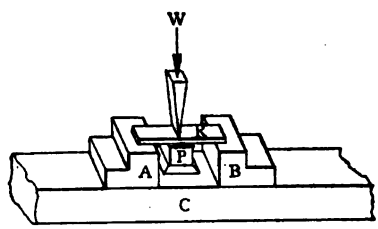

FIG. 297.

As the rod is bent an interference band coincides with the cross hair whenever the thickness of the air film is an odd multiple of $\frac{1}{2}\lambda$ for the light used, that is the depression corresponding to the interval between two successive bands coincident with a cross hair is for sodium light 589.5 millionths of a millimeter.

Denoting the central depression produced by any weight W by n the coefficient of extension in the direction of the length of the rod is given by the formula†

$$E = \frac{4bt^3}{Wl^3} n.$$

* *Wied. Ann.*, XVIII., 325, 1883.

†Groth, *Phys. Kryst.*, III. ed., 203.

SURFACE OF EXTENSION COEFFICIENTS. Nine classes result from the measurements of extension coefficients of crystals.

1. *Isometric crystals* all yield an extension surface symmetrical to nine planes and thirteen axes. The four central sections parallel to the octahedral planes are circles. The cubic axes are directions of maximum or minimum extension and the octahedral axes are correspondingly minimum or maximum.

2. *Hexagonal.* Classes 19, 22, 23, 24, 25, 26, 27. The extension surface is a surface of rotation around c. Each vertical central plane and the horizontal central plane are planes of symmetry.

3. *Hexagonal.* Classes 18, 20, 21. The extension surface has one circular section horizontally through the center. In general the shape is that of a rhombohedron with rounded edges and angles symmetrical to three vertical planes and to a ternary vertical axis. Fig. 298 shows the section of the surface for calcite made by a principal section normal to a rhombic face, the dotted lines being the directions of greatest and least extension. Fig. 299 shows the section normal to this.

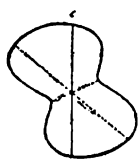

FIG. 298.

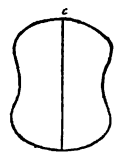

FIG. 299.

4. *Hexagonal.* Classes 16 and 17. Like No. 3 but without the three vertical planes of symmetry.

5. *Tetragonal.* Classes 11, 12, 14 and 15.

6. *Tetragonal.* Classes 9, 10 and 13.

7. *Orthorhombic.* The extension surface symmetrical to the three

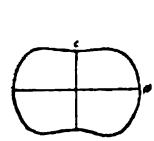

FIG. 300.

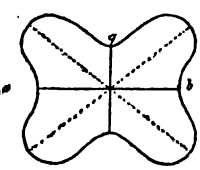

FIG. 301.

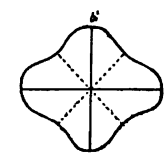

FIG. 302.

pinacoidal planes. Figs. 300, 301, 302, show these sections for barite.

8. *Monoclinic.* The extension surface symmetrical to the clinopinacoid and to the axis b.

9. *Triclinic.* No investigations are as yet recorded.

EFFECT OF PRESSURE IN ONE DIRECTION UPON THE OPTICAL CHARACTERS.

If a rectangular parallelopipedon* *C*, Fig. 303, is compressed between the parallel jaws of a screw press† in general the velocity of the light vibrating parallel to the pressure is increased. If the pressure is uniform the convergent light effects are studied by bringing the specimen over the stage of a polariscope, but if at all unequal, determinations in parallel light of vibration directions, faster and slower ray and strength of double refraction are more safe.

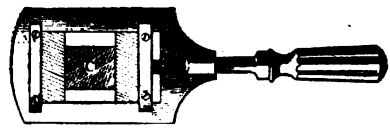

FIG. 303.

Amorphous Substances.

Glass‡ gives under compression a negatively uniaxial figure the optic axis parallel to the direction of pressure; that is *c* parallel a, or the ray vibrating parallel to the pressure is the more rapidly transmitted.

Optically Isotropic Crystals.

In general become biaxial but when the pressure is applied parallel to the cubic (quaternary) or octahedral (ternary) axes the crystal becomes uniaxial.

Optically Uniaxial Crystals (Denoting by a, b, c the principal vibration directions and also velocities).

In positive crystals *c* is parallel to c and $a = b > c$, while in negative crystals *c* is parallel to a and $a > b = c$. Pressure parallel to *c*, in *positive* crystals, will cause c to approach a and possibly to equal (isotropy) or exceed it (negative); while in negative crystals pressure will only make a still greater. In either positive or negative crystals pressure§, parallel *a*, will make the three velocities a, b, c unequal, that is develope a biaxial structure.

Optically Biaxial Crystals.

The relations are more complex. Pressure perpendicular to

* Pockels used rectangular parallelopipeds 13 mm. high, 25.5 broad and thick and compressed from 30 k. g. with quartz to 2 k. g. for sylvite per sq. mm.

† For press recording pressure exerted see Groth, *Phys. Kryst.*, III. ed., 215.

‡ If the pressure is not uniformly applied at all points of the opposite surface the effect may resemble biaxial lemniscates.

§ The centre of each ring system thus developed in quartz is colored, that is parallel to each optic axis there is a rotation, and it has been shown that in these directions two elliptically polarized waves are transmitted.

the plane of the optic axis decreases the axial angle in positive crystals, and the crystal may be, as with heat, p. 114, for a certain pressure uniaxial or the axes may pass into a plane at right angles to their former position; with negative crystals the axial angle is increased. Pressure parallel to the obtuse bisectrix will in positive crystals increase the axial angle and in negative crystals decrease it.

PERMANENT DEFORMATION.

Any strain or pressure in excess of the so-called "elastic limit" produces a permanent change of form.

CLEAVAGE.

In crystals the elastic limit varies with the direction, that is, in certain directions there is a weaker cohesion of the particles than there is in others, and many crystals tend to separate or *cleave* along more or less smooth plane surfaces normal to these directions of weaker cohesion. This is undoubtedly due to the fact that whatever form of regular grouping of particles may exist in a crystal, adjacent molecular planes in certain directions will be further apart than adjacent planes in other directions, and, therefore, held together with less force. For instance, in Fig. 304, it is evident that the closer the particles are along any direction *ab*, *cd*, *ef*, *gh* the greater is the distance to the adjacent row *a'b'*, *c'd'*, *e'f'*, *g'h'*, and as undoubtedly the further apart the particles are the weaker their cohesion, cleavage will be most likely to occur parallel to the planes in which the crystal molcules are most closely* packed.

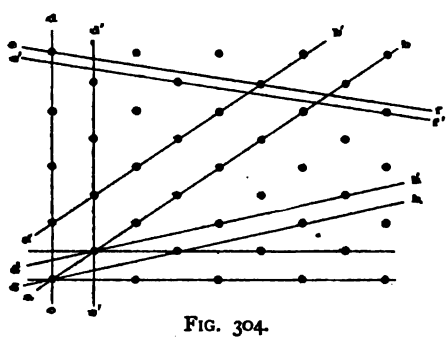

FIG. 304.

The same *general* relations exist for elastic and permanent deformation.† Cleavage will therefore be expected normal to the direction of greatest elastic extension, therefore parallel to faces with simple indices. The possible cleavage directions are:

* The densest planes are usually the faces of common forms with simple indices.

† Groth, *Phys. Kryst.*, III. ed., 229.

System.	*Cleavage Form.*	*Examples.*
Isometric.	Hexahedron.	Galenite.
	Octahedron.	Fluorite, diamond.
	Rhombic Dodecahedron.	Sphalerite.
Hexagonal.	Basal Pinacoid.	Beryl, pyrosmalite.
	Hexagonal Prism.	Nephelite, apatite.
	Rhombohedron.	Calcite, siderite.
	Hexagonal Pyramid (rarely).	Pyromorphite.
Tetragonal.	Basal Pinacoid.	Apophyllite.
	Tetragonal Prism.	Rutile, wernerite.
	Tetragonal Pyramid (rarely).	Scheelite.
Orthorhombic.	Pinacoid.	Anhydrite, topaz.
	Prisms or Domes.	Barite.
	Pyramid.	Sulphur.
Monoclinic.	Clinopinacoid.	Orthoclase, gypsum.
	Basal pinacoid.	Muscovite, orthoclase.
	Orthopinacoid.	Epidote.
	Orthodome.	Epidote.
	Prism.	Pyroxene, amphibole.
	Pyramid (rarely).	Gypsum.

In triclinic crystals there can only be equally easy cleavage parallel to one plane. Nevertheless if there is a direction of nearly perfect cleavage one of the principal vibration directions will be approximately normal to this and the two others parallel thereto.

GLIDING PLANES.

In those directions *ef*, *gh*, Fig. 304 in which the adjacent molecular planes are closest together and therefore most strongly held together it sometimes happens that under tangential pressure the particles glide or rotate, without separation, into a new position of equilibrium.

This phenomenon has been observed in calcite, pyroxene, anhydrite, stibnite and other minerals.

In calcite for instance let *ab'c'd* Fig. 305 represent a section through the optic axis normal to a rhombic face (see *abcd*, Fig. 222) then will *ac'*, the optic axis, make an angle of 63° 45′ with *ad*, the direction of $-\frac{1}{2}R$, and an angle of 45° 23½′ with *ab'* the short diagonal of a cleavage face.

If pressure is applied gradually in the direction of the arrows, that is parallel to *ad* there will be produced about some plane *ef* parallel to *ad* a gliding or rotation of the particles until *eb'* has taken the position *eb* at which $feb = 180° - feb' = 70° 51\frac{1}{2}'$.

In this rotated portion the optic axis will be *bd'* making with the optic axis *ac'* of the unchanged portion an angle of 52° 30′ as shown.

Instead of rotation about a single plane *ef* there may be rotation about several parallel planes as in Fig. 306 producing twin lamellæ.

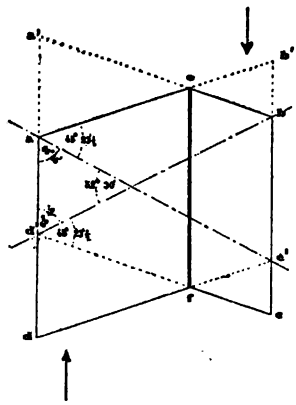

FIG. 305.

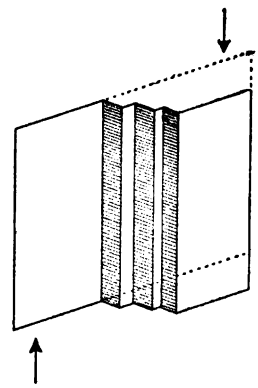

FIG. 306.

If a little calcite cleavage is placed, as in Fig. 307, with an edge *ad* of a larger angle resting upon a steady support and the blade of a knife is pressed steadily down at some point *i* of the opposite edge the portion of the crystal between *i* and *c* will be slowly pushed as indicated into a new position of equilibrium as if by rotation about *fghm*, or $-\frac{1}{2}R$, until the new face *gc'h* and the old face *gch* make equal angles with *fghm*. If carefully done *gc'h* will be a perfect plane, but more frequently it is step like and the rotated portion is apt to separate at the gliding plane.

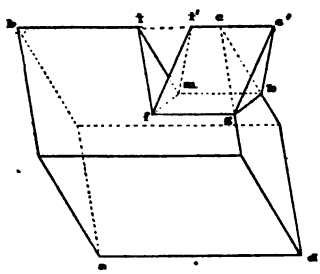

FIG. 307.

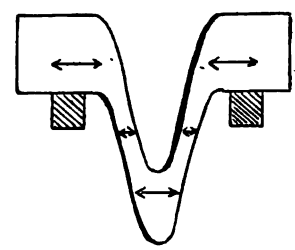

FIG. 308.

In the described phenomenon of gliding the particles evidently assume new relative positions. If however a rod of ice of square cross section is cut with one pair of long faces parallel to the optic axis the other perpendicular to the optic axis and a bending pres-

sure, Fig. 308, applied normal to the axis there is no change in the direction of the optic axis, indicated by the arrows, nor any especial point at which the movement ceases; that is the particles have evidently slipped* without change in orientation. This has been called TRANSLATION.

PARTING.

The planes along which a slipping has occurred, although previously directions of maximum normal cohesion may thereafter be planes of easy separation or *Parting*,† differing from true cleavage, however, because in parting the easy separation is limited to the planes of actual molecular disturbance while true cleavage is obtained with equal ease in any part of the crystal.

PERCUSSION FIGURES.

If a rod with a slightly rounded point is pressed against a firmly supported plate of mica and sharply tapped with a light hammer, three planes of easy separation will be developed as indicated by little cracks radiating‡ from the point, Fig. 309. One of these is always parallel to the ortho axis *b*, the others are at a definite angle *x* thereto of 53° to 56° inmuscovite, 59° in lepidolite, 60° in biotite, 61° to 63° in phlogopite.

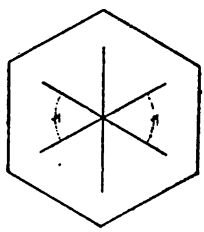

FIG. 309.

In halite, in the same way, on cube faces a cross is developed with the arms parallel to the diagonals of the face, while on an octahedral face a three-rayed star is developed.

CORROSION AND ETCHING.

Liquids or gases do not dissolve or attack chemically a crystal with equal rapidity in all directions.§

This may be shown experimentally by treating a sphere of the crystal in a solvent as, for instance, a sphere of quartz in hydro-

* Mugge, *Neues Jahrb. f. Min.*, 1895, II., 211.

† Similar planes of easy separation may be due to other causes, for instance, during the growth of a crystal the planes at certain intervals may be coated with dust or fine lamellæ of a foreign substance and later the crystal may grow further. This may be repeated several times forming thus parallel planes of easy separation, *e. g.*, capped quartz.

‡ By pressure alone three cracks diagonal to these are developed.

§ Growth and solution appear to be reciprocal and the predominating faces of crystals growing in a solvent are the very planes which oppose greatest resistance to solution in that solvent.

fluoric acid; or plates of different orientation may be placed for an equal time in the same solvent and their decrease in thickness compared.

ETCH FIGURES.

The attack of any liquid or gas upon any crystal face does not commence at the same time at all points but proceeds from certain points first and later from others.

From each point of attack the action proceeds with different velocities in crystallographically different directions and if stopped at the right time the face will be found to be pitted with little angular etch cavities of definite shape. As these increase in number and size they finally reach a stage when they either touch or are separated only by little elevations, etch hills, the sides of which are the faces of the etch cavities.

SHAPE OF ETCH FIGURES.

Provided the same conditions exist of solvent, time and temperature, the etch figures developed on any one face of a crystal will be of the same shape and in parallel position plane for plane. On similar faces the etch figures will be alike, and on dissimilar faces will be unlike.

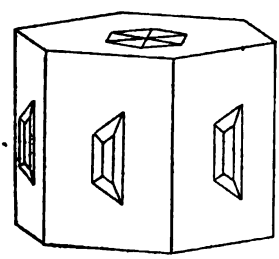

FIG. 310.

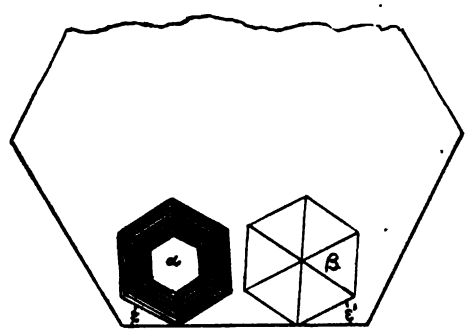

FIG. 311.

The figures produced by solutions of different strength are not necessarily exactly the same, and with different solvents there may be a still greater difference,* as strikingly illustrated by the tests of Baumhauer † upon apatite with hydrochloric and sulphuric acids. Fig. 310 represents the etch figures in general, but

* For this reason it is not safe to assume any relation between the shapes of the etch figures and of the crystal molecule.

† *Ber. Ak. München*, 1887, p. 457.

the basal planes treated with hydrochloric acid show side by side, dark deeply etched figures, usually consisting of a *negative* third order pyramid truncated by the base *a*, Fig. 311; and lighter less deep figures usually a positive third order pyramid, *β*, Fig. 311.

With 100 per cent. acid the dark *a* figures are negative, but approximately second order pyramid, while the lighter images *β* are positive and also near the second order. If weaker solutions are used, the figures are differently oriented. With sulphuric acid still different orientations are obtained.

The following are the average values obtained for *ε*, Fig. 311, for different strengths, 100% HCl being Sp. Gr. 1.130 and 100% H_2SO_4 a Sp. Gr. of 1.836.

	100 per cent.	60 per cent.	50 per cent.	20 per cent.	10 per cent.	5 per cent.	1 per cent.
a figures HCl	(—) 27°20′	(—) 22°57′	(—) 20°48′	(—) 18°44′	(—) 18°21′	(—) 18°5′	(—) 17°34′
β figures HCl	(+) 27°10′	(+) 28°56′	(+) 26°40′	(+) 28°31′	(+) 28°31′	(—) 27°41′	(—) 17°34′
figures H_2SO_4	(+) 13° 7′	(+) 8°35′	(+) 1 to 5°	(—) 19°39′	(—) 16°52′	———	(—) 13° 6′

SYMMETRY OF ETCH FIGURES.

Whatever the solvent, the etch figures conform to the symmetry of the class to which the crystal belongs, and are rarely the limit forms common to several classes. Although the first developed etch figures may be the simple forms bounded by the planes of greatest resistance to solution, these are soon modified by other planes with complex indices, because the saturated solution in each cavity

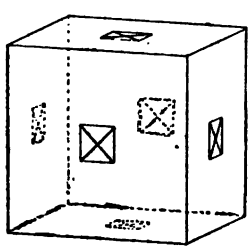

FIG. 312.

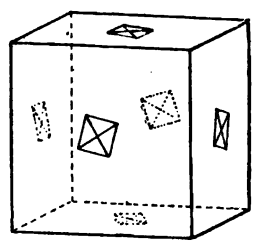

FIG. 313.

is replaced much more slowly near the bottom than near the border, and the attack is slower. The etch figures serve, therefore, as an important means (perhaps next to geometric form the *most* important) for determining the true grade of symmetry of a crystal. For instance, Figs. 312 and 313 show the shape and direction of the etch figures on cubes of galenite and sylvite, respec-

tively. Fig. 314 shows the planes and axes proper to class 32, the highest grade of symmetry in the isometric system. Evidently the

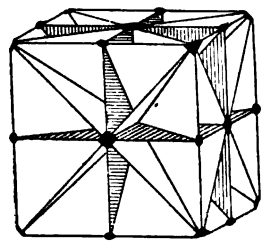

FIG. 314.

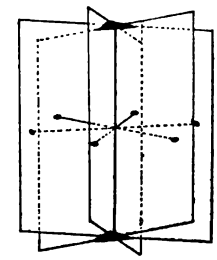

FIG. 315.

etch figures of galena satisfy all of these, whereas those of sylvite are not symmetrical to the planes of symmetry, but are to the axes. That is, galenite belongs to class 32, sylvite to class 29.

Similarly Figs. 316 and 317 show the shape and direction of etch figures on rhombohedra of calcite and dolomite, respectively. Fig.

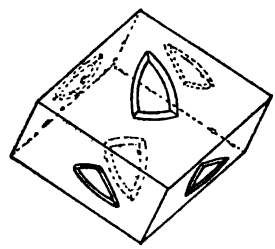

FIG. 316.

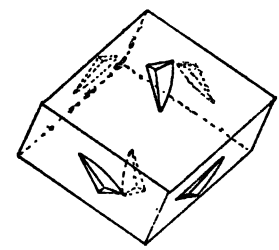

FIG 317.

315 shows the planes and axes of symmetry of class 21. The etch figures of calcite satisfy all of these, while those of dolomite are not symmetrical to the planes of symmetry, but are to the axes. That is, calcite belongs to class 21, dolomite to class 17.

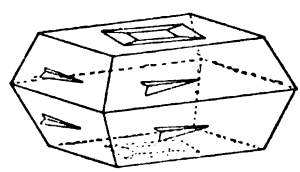

FIG 318.

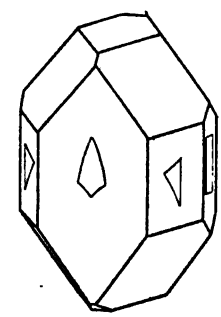

FIG. 319.

Similarly, the etch figures of wulfenite Fig. 318 show the mineral to belong to class 10, and the etch figures of pyroxene Fig. 319 show it to belong to class 5.

MANIPULATION.

No general rule can be given, it being principally a question of ease of solution. The operation may consist merely in a slight pressure from a rag moistened with water, or the sliding of the crystal across a moistened spot in smooth filter paper, or, more frequently, the crystal is immersed for various periods in one of the mineral acids, caustic alkalis, or the mother liquor, hot, warm or cold, dilute or concentrated. High pressure steam, water, hydrofluoric acid, a pasty solution of caustic potash at 100° to 150° C., or even a red-hot fusion of acid potassium sulphate and fluorite have been used.

Natural faces are usually most satisfactory for etching; cleavages are sometimes successfully etched. The etch figures are usually microscopic, and if large are not apt to be sharp and distinct.

CORROSION FACES.

The continued action of a solvent may dissolve away certain crystal edges, replacing them by planes conforming in symmetry to that of the crystal. These planes have been called corrosion faces.

HARDNESS.

The resistance of a smooth plane surface to abrasion is called the hardness, and is commonly recorded in terms of a decimal scale of ten common minerals selected by Mohs. In the light of the later more exact methods it is seen that there is no even approximately common difference in hardness between neighboring members* of this scale.

* Jaggar gives the following comparison of the hardness of the minerals of the Mohs scale (*Amer. Journ. Sci.*, IV., 411, 1897):

Scale of Mohs.	Pfaff by boring with a diamond point.	Jaggar by boring with a diamond point.	Rosiwal by grinding with a standard powder.
1. *Talc*, laminated	———	———	———
2. *Gypsum*, crystallized	12.03	.04	.34
3. *Calcite*, transparent	15.3	.26	2.68
4. *Fluorite*, crystalline	37.3	.75	4.70
5. *Apatite*, transparent	53.5	1.23	6.20
6. *Orthoclase*, white cleavable	191.	25.	28.7
7. *Quartz*, transparent	254.	40.	149.
8. *Topaz*, transparent	459.	152.	138.
9. *Sapphire*, cleavable	1000.	1000.	1000.

More exact methods, in which greater uniformity in pressure, cutting edge, condition and position of surface, etc., have been used by various experimenters. Exner * and others supported the crystal upon a little carriage moving on a horizontal track. The face to be tested was horizontal, the pressure p on the scratching point of steel or diamond was vertical and the carriage was moved back and forth by a weight W. The method preferred by Exner was with W constant to determine the pressure p necessary to produce a visible scratch.

From the results obtained Exner constructed the so-called hardness curves, for instance, Fig. 320 represents a dodecahedral cleavage face of sphalerite, radii are laid off from the center, each of a length proportionate to the value of p, for that direction and

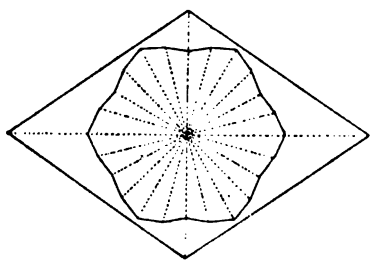

FIG. 320.

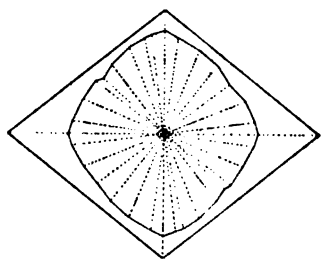

FIG. 321.

by connecting their ends a symmetrical figure is obtained, showing six directions of maximum and six of minimum hardness. Similarly in Fig. 321 a basal plane of barite shows a figure of lower symmetry.

The results of Exner show that the variations in hardness observed in any crystal are dependent upon the cleavages. Faces not cut by cleavage planes have constant hardness in all directions, while faces intersected by cleavage planes show minimum hardness parallel to the intersection with the cleavage plane and if the cleavages are of unequal ease the minimum hardness is parallel to the plane of easiest cleavage. So absolute is this relation that it may be expressed algebraically.

Very similar apparatus was used by Franz and Turner,† the mineral, however, being fixed and the point moving.

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* *Harte an Krystallflachen*, 38, 60, 103, 164.

† *Proc. Phil. Soc. Birmingham*, 1886.

Pfaff* drew a diamond splinter of definite shape 100 times back and forth in one place, then shifted and repeated, widening the groove. The loss in weight of the crystal for the same number of movements of the diamond over the same area and with a constant pressure serve as approximate values for hardness, *i. e.*, hardness is inversely as the loss in weight. Pfaff also used a revolving diamond point. For equally deep penetration the hardness was as the number of revolutions.

Jaggar † designed an attachment to the microscope, in which the point of a cleavage tetrahedron of diamond is rotated at a uniform rate and under uniform pressure until a cut of uniform depth is obtained (measured by focusing on the rulings of a Zeiss micrometer glass, which is slightly inclined and follows the downward movement of the diamond point). The number of rotations of the point varies as the resistance of the mineral to abrasion by diamond.

The effect of grinding has also been used as a test for hardness, for instance, Jannetaz and Goldberg ‡ employed a so-called "Usometer," consisting of a rotating grinding disc, upon which four plates, the hardness of which is to be determined, were pressed by normally acting weights, the loss of weight of each giving the relative hardness.

THE METHODS OF STATIC PRESSURE.

Following the definition of hardness given by Hertz, Auerbach devised a method in which a plano convex lens of any mineral is pressed against a horizontal plate of the same mineral, both are bent and touch throughout a circular space, and for some pressure P the elastic limit is reached, at which there is produced, if the mineral is brittle, a circular fissure, or, if the mineral is tough, a circular permanent indentation.

According to Auerbach § the limit pressure P_1 upon a square mm. of surface varies with the radius ρ of the lens, but the product of P_1 into the cube root of this radius ρ is essentially constant and may be called the Absolute Hardness, that is

$$H = P_1 \sqrt[3]{\rho}.$$

* *Ber. Ak. München*, 1883, 1884.

† Microsclerometer, for determining Hardness of Minerals.—T. A. Jaggar, Jr.—*Amer. Jour. Sci.*, IV., Vol. IV., 399, 1897.

‡ *Ass. franc. p. l. avanc. d. sc.*, IX., Aug., 1895.

§ F. Auerbach.—*Wied. Ann.*, XLIII., 61; XLV., 262, 277.

On this basis he determines * the absolute values of the Moh's scale to be: corundum, 1,150; topaz, 525; quartz, 308; orthoclase, 253; apatite, 237; fluorite, 110; calcite, 92; gypsum, 14.

NOTES ON MICHIGAN MINING PRACTICE.

W. L. HILDBURGH, E.E., A.M.

Introductory.

During the latter part of the summer of 1898 the writer spent several weeks in the mining districts of Northern Michigan. The following notes, principally on mine plants, have been selected from those made at the time, as perhaps of general interest.

Of the mines referred to the Aragon, at Norway, the West Vulcan, at Vulcan, and the Chapin and Pewabic, at Iron Mountain, producing a blue hematite, are on the Menominee Range; the Lake Angeline and Cleveland Cliffs, producing red hematite, are on the Marquette Range, at Ishpeming; while the Atlantic, Calumet and Hecla, and Tamarack, are in the "Copper Country," on Keweenaw Point.

The writer's thanks are due to the superintendents, captains and various bosses of the mines visited for many of the statements contained in this paper.

Methods of Mining.

It is evident that in a paper of this kind no adequate description can be given of the methods of mining employed in the Lake Superior District, since these systems are so numerous and so varied that even a brief mention of them would take more space than is allotted to this entire article. Only a short account, therefore, will be given of two of these methods, as applied to hematite and copper rock respectively.

The lenses of ore at the Pewabic mine are worked at present by the "block" system, or by "sub-levels." Formerly the "pillar and room" system was used, but was so wasteful in ore and timber that it was abandoned, and sub-levelling is now used for the re-

* *Wied. Ann.*, LVIII., 357.

moval of the pillars in the old workings. A saving of ten cents per ton on timber alone is claimed for the caving systems as against the old methods. Mining by the sub-level, or sub-drift system is done in the usual manner. Mining by the block system was first used at this mine, about four years ago, and introduced later into others in the neighborhood. As worked at the Pewabic it consists of driving a main gangway along the formation on one side of the block, then two crosscuts about 180 ft. long and about 250 ft. apart, and a second gangway at their far end parallel to the first. Raises, about 50 ft. apart, a little to one side of the drift, are put up from the crosscuts to within about 20 ft. of the floor of the next level. Then, by underhand stoping, the ground above the crosscuts is taken out, leaving the sides of the block unsupported. From the main gangway and the two crosscuts 6 ft. or 8 ft. drifts, are put in, subdividing the bottom of the block into pillars from 6 ft. to 8 ft. square, depending on the nature of the ground. At the far end of the crosscuts the pillars are drilled and blasted. The ground begins to break there, and continues to break forward, unless the pillars are too strong, necessitating their being blasted out. The whole block breaks up, and the ore is then removed by driving through the broken ground.

Up to this time but little timber has been used, the walls generally being untimbered. Only the raises are timbered, loose slabs supported, water courses held in check, etc. The drifts through the broken ground are now timbered by "spiling," the lagging being slipped forward above the cap pieces to hold up the broken material as the work advances. This system is worked with comparative safety to the miners. Sometimes when the broken rock arches and refuses to fall a stick of powder provided with a fuse is put on a pole, stuck into the arch, a candle applied by the use of another pole, and the arch thus broken.

The copper deposit of the Atlantic Mine is in an amygdaloid bed, dipping at an angle of about 54°, and is worked as a vein. The copper is disseminated throughout the rock, generally in the form of small, fine, scale-like particles, though some large thin plates have been found, as well as a few small masses. Four inclined shafts, a few hundred feet apart along the strike are actively worked, while a fifth is being sunk. In addition there is an old shaft, No. 3, alongside of *D*, used for hoisting men and for a Cornish pump. The deepening of the shafts is done entirely from

D, *D* and old No. 3 being sunk the depth of a level, at present about 85 ft., a drift made on each side to the next shafts, and a raise made connecting with the bottoms of the shafts. The actual mining is done on contract, two shifts, of two men each, driving the length of a contract, and then, leaving a shaft pillar, enlarging the drift by a second slice to "timber height." At this stage stulls are put in and overhand stoping commenced, continuing until the contract is finished. A floor is left between the levels, of a depth dependent on the quality of the vein- and wall-rocks, but generally from 10 to 20 ft.

WATER.

The removal of the water which tends to accumulate in the mines of both the iron and copper regions of Michigan is accomplished by the use of almost every device accepted as good practice at the present time, and in some cases by apparatus surviving from the days when direct acting pumps were far from their present state of, greater or less, perfection. Cornish pumps, water tanks, steam, air and electric pumps are in use in all sizes and in so great variety that it is impossible to give here more than a brief description of the kinds and sizes selected for certain cases.

The necessity of large extra pump capacity in a mine was well illustrated at the time of the writer's visit to the Menominee Range by the effect of a very heavy and long-continued rain. Although enough pump capacity was installed in almost every mine to provide for any ordinary emergency, the extraordinary demands made upon the pumps seriously interfered with their proper working, and in some instances the lower workings were flooded, the pumps, though large, being unable to handle the great amount of extra water. In one case no ore was taken out of any part of the mine for two days, while in several others mining operations were stopped for a shorter time.

The Aragon Mine is very wet, and considerable difficulty has at times been found in disposing of the water, all of which is removed by direct acting steam pumps. In the mine it runs in drains at the side of, or between the tracks, and is very red, due to fine particles of ore carried with it. After leaving the mine it runs in ditches to the Menominee River, about six miles distant. A quite noticeable feature is the steep grade of these ditches near the mine, made necessary by the speed of the current required to carry off the mud in suspension.

In No. 2 shaft are two column-pipes of mild steel, lap-welded, and a 6-in. steam pipe to supply the pump. An 8-in. column pipe runs to the sixth level, a 10-in. to the eighth. At present only the 10-in. pipe is used. In connection with this shaft are the following pumps:

On the fourth level one No. 11 (450 gals.) Cameron plunger pump. On the sixth level one compound condensing pump, capable of raising 800 gallons per minute 510 ft., and one No. 12 (600 gals.) Cameron piston pump. On the seventh level two No. 10 (325 gals.) Camerons. On the eighth level one No. 10 Cameron and one large triple expansion Worthington, capacity 850 gallons at 1,000 ft., or 1,000 gallons at its present depth of 750 ft. On the "eight-and-one-quarter" level one No. 9 Cameron. At present 650 gallons per minute are pumped from the eighth level, and 550 from the sixth.

There is also a water shaft, 73 ft. deep, to remove the surface water which runs into a subterranean watercourse beneath the property. The shaft is 8 x 10 ft., and contains a ladder-way and an 8-in. column pipe. The pump is a compound condensing duplex, and has four 10-in. plungers; its capacity is about 1,000 gallons per minute, though at present only about 500 gallons are raised, because the new shaft, Harrison, No. 4, being sunk, takes some of its water. This new shaft was about 350 ft. deep in August, 1898, and contained one pump, capacity 500 gallons, raising at that time about 200 gallons per minute.

At the West Vulcan Mine, distant about one mile from the Aragon, the drifts and shafts are very wet, and a large underground stream flows through the workings. To take care of the water there are three pumps on the twelfth level, 1,000 ft. below the surface, one of which runs continually. Two of the pumps are direct-acting Worthingtons, the third is a Cornish pump. All the mine water is raised from the twelfth level, and generally amounts to about 850 gallons per minute.

The Cornish pump will throw approximately 1,000 gallons per minute under a head of 1,000 feet. It is calculated to run at five strokes per minute, pumping the water in two stages of 500 ft. each. Its stroke is 10 ft., with 16-in. plungers. The entire pump is in duplicate—two fly-wheels, two rods, etc.—with the exception of the gearing. The engines are geared to the pump in the ratio 8: 1, the large spur wheel being 30 ft. 4 in. on its pitch diameter.

The pump rods, in going from the cranks to the main bobs, have two pivoted joints, where the pitmen are jointed to the horizontal parts of the rods, and where these latter parts meet the parts connected to the bobs. At these points the rod is supported by heavy rods, each mounted on a shaft at the bottom of a small pit and pivoted to the pump rods at the joints in the latter, these devices being used in the place of rollers. This arrangement is shown diagrammatically in Fig. 1. Each of the supports is cov-

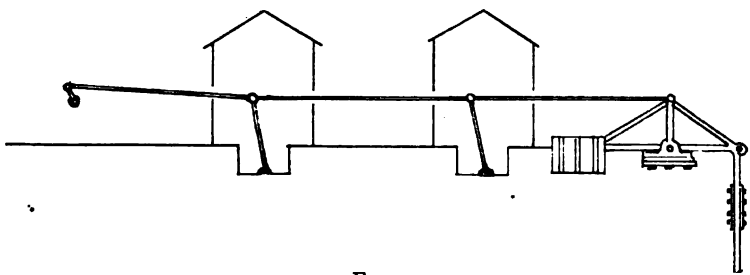

FIG 1.

ered by a small shed of wood and sheet iron, for protection from the weather. The rods are supported by rollers at the points where they enter the building in which the balance bobs are situated.

One of the Worthington pumps, installed in 1893, is a compound duplex, and will raise 1,000 gallons per minute 1,000 ft. The other, installed in 1897, will raise 1,200 gallons per minute to a height of 1,200 ft., and is a triple expansion duplex. In this latter pump, on account of the absence of a fly-wheel, there is a tendency to shorten the stroke, which is 24 ins. normally. An indicating hand, attached to the piston-rod and moving over a scale, shows when this becomes excessive, so that steps may be taken to counteract it. Each of these pumps has a stroke counter, the record of which is reported every morning.

The underground water course can be shut off for about one hour, if necessary during repairs, by plugging a hole in the dam through which the water ordinarily flows. This dam, which is intended simply for temporary work and will not stand much pressure, is pierced by a pipe furnished with a valve, in addition to the hole just mentioned, to allow an accumulation of water to escape after the hole has been closed for a time.

In sinking the Hamilton shaft, at the Chapin Mine, a large body

of water was struck at a depth of about 1,400 ft. It rose rapidly and drowned the pump, while at the same time the water in a neighboring shaft, the Ludington, disappeared. Finally the water in the Hamilton attained its full height, after flooding the Ludington. To remove it bailers were constructed of about 7 ft. × 8 ft. rectangular cross-section, and about 18 ft. total length, with wedge-shaped ends. Each bailer had a slide valve at the bottom of one of the parallel sides, this valve being opened by an attached lever striking a slide on the wall of the shaft. Overwinding was prevented by causing the bucket, on reaching a certain point in the shaft, to lift a heavy weight attached to a rope. When the valve was opened at the top of the shaft the water was carried by its pressure clear of the shaft and into a drain. Shown diagrammatically in Fig. 2.

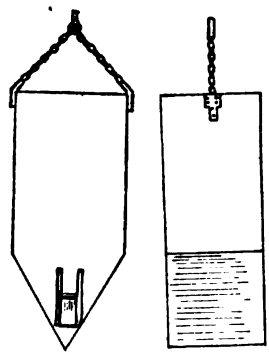

FIG. 2.

A very large Cornish pump, operated by a vertical steeple-compound engine, was erected at this mine in 1892. Lately, on account of the settling of the ground (due to the caving system of mining employed) the engine was unfitted for use in the position in which it had been erected. The foundations were cracked and almost ruined, and there was danger of engulfing the engine in the upper part of the mine workings. At the time of the writer's visit about half of the engine had been removed to a platform in the yard. The engine, one of the largest ever erected for such a purpose, was a steeple-compound, 50-in. and 100-in. cylinders, 10-ft. stroke, designed to work at speeds of five to ten revolutions per minute with 125 lbs. pressure. Its capacity, at the higher speed, was 3,200 gals. per min. 1,500 ft. The fly-wheel was 40 ft. in diameter, weighing 160 tons, and the total height above the floor was 54 ft. It was arranged to operate either by steam, or air furnished by a compressor plant at Quinnesec Falls, about three miles distant. The traveling crane, above the engine, was operated entirely by hand.

In the Pewabic Mine, at the fifth, or lowest level, 700 ft. below the surface, is one of the finest mine pumps in the world, a Worthington duplex, tandem triple expansion pump, with a capacity of

1,000 gals. per min. to a height of 1,000 ft. The cylinders are 15 in., 23 in., and 38 in., the plunger 12 in., and the stroke 24 in. At a point in the column pipe, just above the pump, are a clack valve and a gate valve. On stopping the pump for repairs the clack valve closes, after which the gate valve is closed, thus confining the water in the column pipe. To start the pump again the gate valve is opened, and the clack valve then opened naturally by the pump pressure. An old compound duplex pump is kept for emergencies. The pumps were moved from the third directly to the fifth level, as the fourth and fifth levels were run at the same time.

At the Atlantic Mine, near Houghton, is a Cornish pump installed about 20 years ago. It is single, has an 8-ft. stroke, with 20-in. plungers, and a speed of 6 strokes per min., raising the water 1100 ft. in four lifts, 100 ft., 300 ft., 400 ft., and 300 ft., respectively, beginning at the bottom. The engine develops about 450 H. P., and has a 24-ft. fly-wheel.

The Tamarack Mine is remarkably dry. Notwithstanding its size and great depth only about 160 tons of water are raised per week, a 3-ton water tank being connected to the hoisting rope once a day. One or two very small direct acting pumps, run by air pressure, are used for transferring the water from different parts of the mine to the sump.

Several mines at Ishpeming have Cornish pumps, operated at a considerable distance from their engines by heavy wire ropes connecting the pitman (or a rod attached to it) to the pump rod. When the direction of motion is to be changed horizontally or vertically connections are made to a triangular bell-crank.

TRANSPORTATION.

The mine cars at the Aragon are of steel, and quite small, the larger size holding about 1¼ tons, the smaller, weighing about 500 lbs., about ½ ton. The large car bodies cost about $35 each, the four 40-lb. manganese steel wheels, at 8c. per lb., $12.80 more, making a total cost of about $50 each, for the 1¼-ton cars. Tramming is all done by hand, as the longest distance run is about 600 ft. Light rails are used. The gauge of the track is 24 in. About 1,200 tons of ore are taken out per 24 hours. The cars are changed, in a wide gangway, from one track to another by grasping with a device like a double pair of ice-tongs (four prongs,

two for each side of the car), hung from a flat iron bar across the timbering. On this bar runs a small, double-flanged wheel, from whose axle is hung a lever, on the short arm of which is the gripping device, and on whose long arm the men put their weight to lift the car: when the car is in the air the whole arrangement is rolled along the bar until over the other track, to which it is lowered. The cars are dumped by cylindrical cradles, built of steel rails, into which they are run, and are swung over by hand.

At the West Vulcan mine the cars are hauled by mules. The mules are brought into the mine by placing each in a high, narrow, wooden box, which opens at both ends and at the top. After the mule has entered the ends and top are closed, and the box rolled onto the cage and lowered. The car bodies, of steel, and top-dumping, hold 35 cu. ft., or about 2 tons each and weigh about 1,000 lbs. The axles weigh about 65 lbs. each, the iron wheels, now in use, about 91 lbs. each, and those of manganese steel, to be used in future, about 53 lbs. each. Present total weight of car is 1,500 lbs., weight with new wheels will be 1,350 lbs. The use of manganese steel for the wheels of mine cars is rapidly increasing, due to its superior hardness, strength and toughness. The cars at the Pewabic Mine are of steel, capacity 1 ton, weight about 500 lbs., running on 24-in. gauge. Tramming is done by hand, the longest tram being about 800 ft. There is a rope haulage system underground, but it is generally not used when more than one grade of ore is being transported * because when several classes of ore are being handled the complication of switching becomes too great, and little or no time is gained.

Tramming at the Atlantic mine (copper) is all done by hand, the short distances between the several shafts making this the most economical method. The cars are low, and open at both ends, the finer material being held by walls built up of the larger lumps of ore. The cars dump themselves into the skips, being run onto a pair of bent rails, pivoted so as to drop the forward end of the car and allow the rock to slide out.

At the Lake Angeline Iron Mine, near Ishpeming, all the haulage in connection with the East End, or Lake Shaft, is electrical. At the two other shafts hand-tramming is employed. Only the electric haulage will here be described. The longest haul is about

* Four classes of ore are produced at the Pewabic mine.

1,000 ft., the shortest 200 ft., even the latter being taken by the locomotives, on account of some hard curves and because the cars are large and heavy. The trains, generally of five cars each, are made up by hand, and hauled by a motor to the shaft. Then, by a series of switchings on the double track at the shaft, the motor is placed behind the cars to push them close to the shaft. Here a gang of three trammers takes and dumps them into skips holding one carload, 2½ to 3 tons. The succeeding operations are described in another part of this paper. The shaft is an incline, becoming vertical near the surface.

Two similar General Electric Company locomotives are engaged in the underground work,* each 30 H. P., and capable of exerting 1,500 lbs. drawbar pull at a speed of 8 miles per hour. The motors are iron-clad and waterproof. The grade is 8 in. per 100 ft. in favor of the loaded cars. It was said that, under favorable circumstances, 20 loaded cars, 4¼ tons total weight each, had been hauled by one locomotive. Great satisfaction was expressed with the work of these locomotives, and it was said that the plant was soon to be enlarged by the purchase of several more. The motors were controlled by rheostats, nearly worn out at the time of visiting, which were to be replaced by General Electric Co controllers. The rheostats are of iron and mica, and get exceedingly hot, fusing the iron (or the oxide formed) into small globules, and consequently fail. After some use the resistance increases so that only the last few segments are available, and the constant and great arcing which occurs on moving the handle quickly cuts the contacts on these so as to render them nearly useless. This method of failure is not due to mine conditions in particular, but is a fault of rheostat-control in general, and is one of the reasons which has caused its abandonment for surface traction. Besides these motors there are a couple of small portable, electrically driven and operated, hoists to lift timber up the raises made in connection with the top-slice caving system.

The trolley wire is $\frac{5}{16}$ in., and has no feeders, the main meeting it at the shaft. It is covered by an inverted wooden trough (⌐¬) for protection from the men's tools, drippings, etc., and to prevent injury to the men from the wire. As the potential difference between the wire and the rails is about 500 volts, a current, more or less dangerous, can pass if the men's boots are of leather or not ab-

* Only one runs at a time, the other being kept for emergencies.

solutely tight, as they seldom are when partly worn. Lights at the shafts, curves, etc., are run five in series. The tracks are 30-in. gauge, of 30-pound rails on 4-in. hemlock ties. The rails are bonded together, except at switches, where a copper wire is attached to both rails.*

The haulage at the Lake Shaft of the Cleveland Iron Mining Company is also done by electric locomotives. There are three of these underground, one on the first level, two on the second, and, in addition, a timber hoist like the one at the Lake Angeline Mine. One of the locomotives on the second level and one on the first are similar, viz., General Electric Company motors with rheostat control. Each is used steadily for hauling trains of five or six loaded 3-ton cars at speeds up to about 10 miles per hour. Formerly these motors were controlled by the use of the trolley pole alone, but there was so little variation in speed, and so much danger to the motors that rheostats were added. Short trolley poles are used, of the regular pattern, turned by hand whenever the locomotives are reversed. The motormen prefer these to the double angle poles, as being easier to handle and less liable to foul. The third motor, in use on the second level, was built by a company accustomed to the building of mining machinery, but is rather unsatisfactory in several respects. It is built too light, and is thus unable to haul much of a load. This could, of course, be remedied by weighting the motor, but for its present work that is unnecessary. In addition, the large spur wheel of the gearing is down almost to the level of the rails, and gathers mud and grit so as to rapidly wear out its pinions. This is especially bad in mining work, because in some places the mud and water cover the tracks. The work on the second level often has to be done very rapidly, and the regular method of operation, which also admits of quick work, is as follows: The G. E. C. motor hauls the loaded cars near to the shaft, and then goes alone for more loaded cars. The other motor switches the cars, brings them to the loading place for the skip, and hauls the empties back, as it can do this work satisfactorily without weighting, though sometimes the wheels slip around when heavy loads are hauled. This method is quicker, it is claimed, than hauling the empties by the G. E. C. motor. The trolley wire is supported and protected only by a single board above, instead of the inverted trough used at the Lake

*Bonding is often broken and not replaced, as it is not found to be essential.

Angeline, and has no feeders. About half the present length of the line was originally installed by the electric company; the remainder has since been put in by the company operating the mine. The tracks are 40-in. gauge, the rails 40 pounds per yard.

Hoisting Engines and Appliances.

The large hoisting engines required to raise the great daily output of many of the Michigan iron and copper mines makes the employment of the Corliss valve gear almost a necessity in most cases. and but few of the engines are provided with other types of valves, Almost all the engines are duplex, though in a few cases single engines, whose valves can be moved by hand to carry the piston past the dead center, are used. In one place an old rolling mill vertical engine is used for hoisting, the drum being pried around if the engine happens to stop on its center, or the skips allowed to drop a short distance until the piston is in position, and then raised or lowered. This engine is geared to its drum, the pinion on the engine shaft being moved in and out of gear with the spur-wheel on the drum by a steam cylinder and piston parallel to the drum shaft.

The machinery for No. 2 shaft at the Aragon has recently been installed. The engine house is of corrugated iron over wood, and contains one drum driven by a pair of engines. The latter are Akron Corliss, 18-in. cylinder by 42-in. stroke, about 70 R. P. M. at full speed, and take 80-lb. pressure on from $\frac{5}{8}$ to $\frac{3}{4}$ stroke when run singly. Maximum rope speed 2,000 ft. per minute. At present the cages are balanced, and the cut-off is at about $\frac{1}{3}$ stroke. Steam is shut off when the up-going cage is about 200 ft. from the surface. The exhaust was into the atmosphere at the time of visiting, but a feed-water heater was to be put in to utilize the waste steam. The shaft is 800 ft. deep. The rope is of steel, $1\frac{1}{4}$ in. diameter, 1,000 ft. long, and stretches about 2 ft., nearly its maximum, after two months. A Pitkin patent drum is used, consisting of a single cylindrical drum 6 feet in diameter, in two parts, about 2 feet of the right end being connected to the right hand engine, though set loose on the shaft, and fastened to it by a steam friction clutch. The left end of the drum is tight on its shaft and is connected to the left-hand engine. This arrangement allows the cages to be run any distance apart, as the division of the drum gives a certain independence of action in raising or lowering either alone. There is

an indicator for each part of the drum. Six controlling levers are used. In order, passing from the left side, they are: left engine brake lever; steam lever; steam reversing gear lever; lever for operating both brakes; right engine brake lever; steam friction clutch lever. Signalling is by a vibrating electric bell at each engine.

The engine house at the West Vulcan contains the hoisting machinery for C and No. 2 shafts. The engines for the former are single expansion, Corliss, exhausting into a Deane condenser. The ropes are 1¼-in. steel, and wind on 12-ft. drums connected by steam friction clutches to the engines. The drums, though intended to run with the cages balanced, were running unbalanced at the time of visiting, with an engineer for each. When the cages are balanced only about half the steam is used that is needed when they are run unbalanced. Signals are given by an electric single-stroke bell, the number of strokes being recorded by a device described elsewhere in this paper. To prevent overwinding a long sprocket chain, running to the roof, is geared to the shaft of the drum. When overwinding takes place a projection on the chain strikes a trigger, releasing a weight which operates levers to put on the steam brake and to shut off steam by closing one of the valves.

The hoisting engines at D shaft of the Chapin Mine are of the Corliss type, and are generally run by compressed air from the plant at Quinnesec, to be described later, though they are arranged to be operated by steam if desired. The engineer in charge stated that no trouble was experienced in changing from one power to the other. While running on air the lower half of the cylinder ends were coated with oil, apparently to prevent rusting by condensed moisture deposited by the cold produced on the expansion of the air in the cylinder. Two flat ropes, ½ in. x 5 in., run over and under on a pair of reels, each of which is fitted with a hand-operated friction clutch and an air (or steam) brake. These brakes, consisting of a band of iron above and below the wood-coated friction-surfaces of the reels, are used only when the reels are run unbalanced. The brakes generally used are also moved by power, and are strips of iron gripping only the under surfaces of the crank wheels of the engines. The friction surfaces are of wood, covered with white lead to increase the grip.

Shaft No. 4, at the Quincy Mine, is inclined and 4,400 ft. deep. The skips, weighing about 1½ tons and carrying about 3 tons

each, are always hoisted in balance. Each rope is 1 ¼ in. in diameter, and weighs about 5 ½ tons. The engines, both 60-in. stroke, are of different size, one having a 30-in., the other a 26-in. cylinder. The smaller only was originally installed, the larger being brought up later from one of the stamp mills. Slide valves are used on both. The time of hoisting from the bottom is about three minutes. The engineer begins to shut off steam in the neighborhood of the 30th level, as otherwise the engines have a tendency to race. The indicators consist of sprocket chains, running over light shafts near the ceiling, to which numbered iron pieces are fastened, each piece registering with a fixed mark when the corresponding level is reached. The drum is 22 ft. in diameter, and a little over 8 ft. wide. Its surface is of wood, on a skeleton iron frame. The brake surface at each end is of iron, to which wood-lined brakes are applied by hand power. The drum is geared in the ratio ¼ to the engines, the spur wheel being about 19 ft. in diameter. The two ropes wind under and over, following each other across the drum, one winding in the grooves vacated by the other. In winding they are separated by three grooves. They are guided along the drum by rope-carriages on screws turned, by bevel gears, from a vertical shaft bevel-geared to a horizontal shaft which in turn is bevel geared to the drum shaft. The carriages, or fleet-gearing, run on a pair of guides, and carry nuts in which the screw turns, forcing them ahead. The sheaves, one on each carriage, lie in a horizontal plane. The ropes are fastened to the drum shaft by a chain to which they are clamped, and which takes up the strain. The slack of each is wound on a small wood and iron reel between the arms of the drum.

The engine house at No. 2 shaft of the Quincy contains two 48-in. diam. x 84-in. stroke, simple, non-condensing, Corliss geared engines, installed by the Allis Co. about three years ago, direct connected to a 28 ft. drum. The engines together develop about 2,400 H. P. The shaft is nearly 5,000 ft. deep, the rope speed 3,000 ft. per minute. The pistons are in part supported by tail rods, passing out of the rear cylinder heads, and fastened to cross-heads running on guides. The same plan is adopted at No. 3 shaft of the Tamarack mine. Both the brake and the reversing gear are worked by large steam cylinders. To prevent the steam from acting too rapidly a smaller cylinder, filled with oil, is placed above the working cylinder, to act as a dash-pot. The brake is taken off by steam

alone, but goes on by the combined force of the steam and a heavy weight. The brake is formed of an upper and lower band of iron acting on a wooden friction surface, on which, to prevent burning, water continually drips. The drum is grooved, and is entirely of iron and steel. There is a small reel on the shaft, inside the drum, to assist in holding the rope. It is wound by turning a worm which gears with a worm-wheel, the latter being on the same shaft with a pinion meshing with an interior-toothed wheel fastened to the reel.

A device used to stop overwinding by the 2,000 H. P. Corliss engines at No. 2 shaft of the Tamarack gives good results, but is unsatisfactory to the engineers, because when overwinding takes place the levers are jerked violently out of their hands. A carriage, formed of a large nut provided with shoes, travels along a guide, being moved by a heavy, square-threaded screw, about 3 ins. in diameter, near the floor. Turning with the screw at either end of the travel of the carriage is a stop, a projection of which engages a projection on a sleeve on the carriage. This sleeve gears with a pinion, inside of the carriage, sliding on a slotted shaft. When the sleeve turns it turns the gear-wheel on the slotted shaft, carrying this shaft around with it. The motion of the slotted shaft is communicated by a lever to a main shaft, which, turning, by a series of levers shuts off steam and operates the brake and reversing gear. The stop, which, of course, requires accurate adjustment, consists of two parts, one of which locks the other in position. The locking part turns on a series of fine left-handed threads cut on the coarse right-handed threads at each end of the driving screw. The entire stop, therefore, turns with the screw, and, when overwinding brings the carriage near enough, engages and turns the sleeve. The turning of the main shaft is assisted by a heavy weight, which, however, makes the apparatus difficult to re-set.

The Whiting, or Red Jacket, shaft of the Calumet and Hecla is 4,900 ft. deep, and is divided into six compartments, four of which are in operation at present. The hoisting machinery is in two stone buildings, the smaller, 36 ft. x 69 ft., containing the machinery used in sinking and as an auxiliary hoist, the larger 70 ft. x 220 ft., containing the machinery for the main hoisting at the shaft. The system of hoisting employed in both the main and auxiliary houses is the same, the apparatus differing only in details. It is known as the Whiting, a modification of the Koepe

system. In the auxiliary plant the rope, which is attached to two cages, passes from the top of one cage over a sheave at the top of the corresponding compartment, and a sheave in front of the engine house, to two wood-lined sheaves or drums placedand connected tandem, about which it makes three turns. Thence it goes into the tail-house, around the adjustable sheave there, and over several fixed sheaves to the top of the second cage. A diagram of the arragement, showing the main sheaves, is given in Fig. 3.

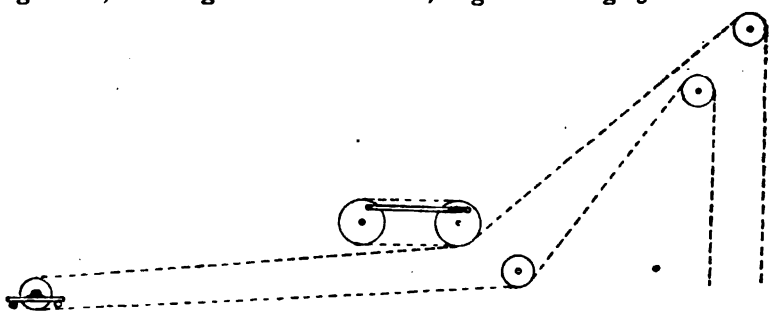

FIG. 3.

The two driving engines are condensing Corliss horizontal tandem compound, cylinders 16 in. and 32 in. diameter by 48-in. stroke. The two frictional driving sheaves, on each of which is a brake surface, are joined by a connecting rod. The indicator is a steel ribbon, through which holes are punched for sprocket teeth to pass, to which the level numbers are clamped. A speed recorder is attached to the engines. Overwinding is prevented only by vigilance. The tail-house is an iron shed about 600 ft. in length, along the sides of which run two heavy iron bars punched with holes about 3 ft. apart. On these, as rails, runs the sheave carriage, on which a horizontal sheave is mounted. The carriage consists of two parts; one fastened to the two bar-rails by pins through a hole in each, the other a large nut, bearing the sheave, which is connected to the first part by a heavy screw whose length is somewhat more than 3 ft., the distance between adjacent holes. Thus an adjustment of any part of 1,200 ft. may be made on the rope in the tail-house.

The main hoisting machinery consists of two pairs of triple expansion, marine type, engines, three cylinders, 20⅛ in., 31¾ in. and 50 in. diameter, by 72-in. stroke. A load of ten tons can be hoisted at a speed of 60 ft. per second. The driving sheaves are considerably larger than those of the auxiliary hoist. Of the two pairs of 3,000

H. P. engines installed, only one was in operation at the time of the writer's visit, running two of the four compartments in use at that time. There is room in the engine house for a third hoist of the same size. A large traveling crane, requiring the power of four men to move it, spans the building. The ropes run through the engine foundations in narrow, high passageways. Brakes and reversing gears are run by oil pressure. On the floor beneath the engines is a set of steam pumps, an accumulator, and a tank for maintaining the oil pressure, together with the feed-water pumps and the hot-well, an elevated steel structure. The safety device, to prevent overwinding, consists of a screw, run by bevel gears, which drives a nut to strike a pin. This pin, moving levers, admits oil pressure to a cylinder connected to the brakes, reverse, etc. At the south end of the engine house is the sheave house, 32 ft. × 43 ft. At the north end is the tail-house, a brick and stone building 32 ft. × 412 ft., having three tracks, carriages, etc. The carriages are of the same general form as the one for the auxiliary hoist, except that the sheaves are vertical instead of horizontal. The two parts of the rope, to the sheave, lie in the same vertical plane, one above the other. The upper division of the rope is brought from the level of the cellar of the engine house to the top of the adjustable sheave by a series of small pulleys mounted on movable standards. The rails for the carriage are I-beams.

Compressed Air.

The machinery in the Mackinac Compressor House of the Calumet and Hecla Co., rather unusual both in size and design, was started early in August, 1898. There is one engine, 7,500 H. P., running three duplex compressors and a large sheave arranged for rope driving, which acts also as a fly-wheel. This engine is of the triple-expansion marine type, with four vertical cylinders. Reheaters, using live steam, are placed between the high and the intermediate, and between the intermediate and the two low pressures.

Each of the similar halves of one of the duplex compressors consists of a horizontal cylinder, in which a piston reciprocates, between two vertical cylinders containing water. The piston, a "torpedo-shaped" iron casting, is connected to a rod passing through a stuffing-box at one end of the horizontal cylinder, and, passing forward and back, alternately raises and lowers the water

in the vertical cylinders, making that act as the real piston in each. The inlet valves are opened by the atmospheric pressure and closed rapidly by mechanical means. The exhaust valves are opened by mechanism and closed by atmospheric pressure. Water for cooling and saturating the air is supplied by a small pump, driven from the main shaft of the engine, which forces a spray into the two vertical chambers alternately. To prevent the air pressure in a cylinder attaining too high a value a device operated by air and electricity is used. This consists, in principle, of a column of mercury lifted by the air to make an electrical contact when the pressure becomes too high, thus starting an electric motor which opens a valve in a small pipe admitting air to a cylinder above the inlet valve, keeping the inlet valve open until the pressure is reduced. This relief system is said to be imperfect, in that the water splashes out when an inlet valve remains open.

The Hydraulic Power Mining Co. utilizes a part of the water power of the Upper Falls of the Menominee River, at Quinnesec, near Iron Mountain, to compress air furnished to run the machinery at several of the shafts of the Chapin Mine, and a little of that at the Pewabic. The plant was originally erected about fifteen years ago, but was rebuilt in 1888. As the Falls consist of steep rapids a weir dam has been built, giving more height and storage capacity. At the Lower Falls, a few miles down the river, there is a mill for the manufacture of paper pulp, the logs for which are floated down from the upper part of the river over the dam at Quinnesec. The water for the turbines flows through a coarse wooden grating to gates controlled by gearing protected by a shed, and thence through a flume 500 ft. long, 50 ft. wide and 15 ft. deep to the gates at the penstocks. The flume frame is of upright wooden posts, tied together by transverse iron rods, lined with plank, and provided with a cement bottom. About half way to the penstocks the flume is divided into two parts, that nearer the river being seldom used because of the danger and greater likelihood of failure. In front of the gates at the penstocks is a second, finer grating, which prevents the entrance of chips from the logging camps to the turbines. The waste weir, just in front of this grating, serves partly as a discharge for the accumulated chips.

The penstocks are of steel, 7 ft. in diameter and 49 ft. from the surface of the water to the turbines, the latter being a few feet above the river level, with a free opening. The turbines, four in number,

of 1,000 H. P. each, are regulated by hand-operated shutter valves. Each is connected by vertical shafting and bevel gearing to two single-stage Rand compressors furnishing air at 60 lbs. pressure. The machinery is stopped four times per 24 hours to grease the gearing, ordinarily kept covered by wooden boxes attached to a series of cords, over pulleys on the beams above, to facilitate their removal. The compressors have 34-in. cylinders, 16 valves at each end, with the cylinders, cylinder heads, and pistons water-cooled, and deliver the air at a temperature of about 250° F. The air is carried about 3 miles through a 22-in. pipe, and loses, it is claimed, only from 1 to 2 lbs. pressure. This small loss is due to the large size of the main as compared with the volume of air. The pipe is of ⅜-in. steel plate, made in flanged sections about 48 ft. long, each section resting on a small piece of tube as an expansion roller. Bends are gradual and few in number, trestles, some of considerable height, being erected where necessary. Provision is made for the expansion by sliding joints at bends. There is a continual noise along the pipe, due to its action as a sound tube and to the motion of the air, and in addition a popping sound, at some places, for which no explanation could be obtained.

Surface Handling of Ore.

At the copper mines the ore is hoisted to a rock-house covering the mouth of the hoisting shaft, where a rough sorting takes place. The following arrangement is generally used in rock-houses in the "Copper Country."

The rock falls on a grizzly, and the coarse material is quickly picked over by a gang of men. The poor rock goes direct to the dump, stamp-rock to the jaw-crushers, and the mass copper is set aside for shipment at intervals to the smelting works. When a piece of copper rock is too large for the jaw-crushers it is broken by a drop or a steam-hammer. The drop-hammer generally used consists of a long iron weight running in guides, lifted by means of a friction pulley arrangement, and held in place while the rock is put into position on the anvil by a piece of wood slipped through the frame, and under it. From the crushers mentioned above the ore drops either directly into the bins, or goes to two smaller crushers on the floor below, and thence to the bins. Between the first and second set of crushers a man picks out particularly rich pieces of rock, and also breaks up with a hammer pieces which have come through the

first set without being properly crushed, or from which poor rock can be separated. There are also, generally, one or more cranes, operated by friction rollers, for handling large masses of rock. The crushers, drop-hammers and cranes are run from lines of shafting driven by a mill engine erected near the crushers or on the ground floor. The ore is transported by rail to the stamp mills, most of which are on the banks of Portage and Torch Lakes. Formerly some milling was done on the shores of a narrow part of Portage Lake, near Houghton and Hancock, but so much sand was run into the ship channel there that it was in danger of being filled up and the Government compelled the mills there to stop. Within the past few years the Atlantic mill has been removed from Portage Lake to the shores of Lake Superior. The stamped material is concentrated until the product contains in the neighborhood of 80 per cent. of copper, and is then shipped to the smelting works.

In the iron regions the large amounts of ore produced, and its low value per ton, render necessary the most economical methods of handling possible. The cheapest method of transportation is, of course, by water, and is used wherever applicable, the ores being hauled by rail to the Great Lakes and then conveyed by specially constructed steel vessels of large capacity to Chicago, Cleveland and Buffalo. Navigation on the lakes can only be accomplished during the warmer months of the year. During the winter the ore, wet as it comes from the mines, is likely to freeze into a solid mass and to the cars used in taking it from the mine. Hence in winter the ore is stored in stock piles at the mines as described farther on.

In summer the mine cars in which the ore is brought to the surface are run over the bins and dumped, according to their construction, by cradles, or from the end or side. These cars are generally trammed by hand and are switched from the tracks leading from one bin to those of another by tarantulas (heavy sheet-iron plates), turn-tables and similar devices. Sometimes, instead of putting a line of track to a cradle over each bin, the bins are placed in line and a single track laid over them. On this track is a low truck carrying a cradle into which the mine car is run, the whole arrangement being then brought over the bin in use and dumped. Occasionally, instead of using a device of this kind to carry the cradle, a low car running on a track at right angles to the tracks over the bins, is used to bring the cars from the main track to that over any bin.

When skips are used for hoisting they may be dumped directly into bins, or into cars, which are trammed mechanically or by hand, and treated like the mine cars just mentioned. Mine cars are also dumped, at some places, into these trestle cars for dumping into bins.

The Hamilton shaft of the Chapin Mine has four compartments, two small ones for cages, and two large ones containing 5-ton skips. The mine cars brought up on the cages are dumped into end-dumping, iron-lined wooden cars, which are run out to a chute from which the railroad cars are loaded. The skips dump automatically at a point a little lower than the cage landing. There are two bins; the skips dump directly into the first, which is close to the shaft, but to reach the second the ore must be transferred to one of a pair of cars running over both bins. These cars have W-shaped bottoms, and may be dumped by hand or automatically. They are moved back and forth by a rod attached to the piston of a long air cylinder about 6 in. in diameter, the air being admitted to either side of the piston by a controlling lever.

The skips at the Lake Shaft of the Lake Angeline Mine hold one carload, 3 tons each. They are dumped, at the top, into one of two trestle cars, each hauled by an electric motor. The locomotives, which were made by the General Electric Company, run on 500 volts, and have a draw-bar pull of 1,000 lbs. at a speed of six miles per hour. They are fitted with controllers and brakes and have short trolley poles of the ordinary form. The rails are connected to a supplementary copper wire fastened to the planks on which they rest.

In the usual method of procedure three men are employed: a motorman and two laborers. A car is pulled back from the bins at the end of the trestle, and left where the skip will dump into it. The motorman jumps into the other locomotive and pushes the other car out to the end of the trestle, slowing as he approaches the buffers which prevent the car going on into the bin, and strikes these buffers with just sufficient force to enable the laborers to easily tip the car to dump its contents out of the end. If the laborers do not catch the swing of the car just right the locomotive goes back a few feet and repeats the operation of striking the buffer with the car. If the swing of the car body is caught exactly at the proper moment one laborer can dump the car, but this is rather hard to do, and too exhausting to be kept up regularly.

The locomotive then pulls the car back to its place under the dumping place of the skip, the motorman enters the other motor, the laborers jump onto the car, and the operation is repeated. The cars are hauled along the trestle much more rapidly than they could be handled by trammers, and dump into the bins or rock piles, in the manner described, in summer, and onto stock piles in the winter. As many as 314 skiploads have thus been handled in 10 hours, including a haulage of perhaps 300 ft. in each direction and around two curves. The system, taken altogether, is very satisfactory and will probably soon be installed in other mines in the vicinity.

Among the faults of the system, as operated at present, may be mentioned the following, due principally to the severe winter weather. The signals may fail and the skips dump onto the motors, though this has happened a number of times, with no damage to the strongly built machines. Sometimes a motor runs off the track at one of the curves, which is quite sharp, and is prevented from falling only by the guard rail, though it has happened more than once that the motorman has had to leave his machine in a dangerous position, over the edge. A minor fault, which could easily be remedied by a small heating device, is that the sand freezes in the sand-boxes in winter.

In forming a stockpile for storing the winter product of an iron mine, the first step is the covering of a level piece of ground, graded if necessary, with 2-in. planks laid close together. Leading to and over this from the shaft house is a temporary trestle, built of rough logs, on which the cars are run out and dumped in the ordinary way, the trestle being lengthened from time to time as necessary. Sometimes a retaining wall is built about the bottom of the pile, of the larger lumps of ore, and billets of wood.

A large steam shovel running on an unballasted track alongside the pile is used for loading the ore for shipment by rail. The cars and locomotives are run on a similar line of track parallel to the first. The track is shifted, as required, by a gang of men with crowbars, and is usually divided into sections convenient for handling. The shovel is run the length of the pile and then its track and the car track are moved toward the pile so that another slice can be taken off. The steam shovel removes almost all the ore directly; the little ore remaining on the planks after it has passed is shovelled by hand into piles large enough to be taken

by the dipper. After taking off the cap pieces of the trestle the posts may be removed from the pile of ore by attaching chains and lifting with the steam shovel. Finally the wood flooring, which has prevented foreign matters being taken up with the ore and has facilitated the work of the dipper, may be taken up for use elsewhere, or allowed to remain for the next winter's stock pile. The dippers of the shovels in general use hold about three tons, and can load a twenty-four-ton car in two to three minutes. The cost of loading ore from stock piles by steam shovels generally runs from four cents to five cents per ton. Hand tramming, rope haulage and electric motors are among the methods of moving the cars on the trestles, the systems of mechanical haulage being more or less automatic in their action. In many cases special trestle cars are used, as in the dumping of the ore into bins for immediate use, thus facilitating mechanical handling. They are generally of the ordinary form of surface car.

At the time of the writer's visit to the West Vulcan mines three trestle cars of a new design were being constructed according to plans of Mr. Roberts, the boss mechanic. Two of the cars were intended for regular work, the third for use in case of emergencies Each car, of 40 to 42 cu. ft. capacity, is to receive the contents of one of the mine cars, 35 cu. ft. capacity, the extra space being allowed for the imperfect packing of the ore when dumped into the trestle car. The cars will be attached to an endless rope, one to each side, and will simply run forward and back on the trestle, the rope reversing its direction for the trips to and fro. One car will dump on each side of the trestle. There will be five dumping places on the trestle, with a tripping device at each. On the car will be a plate, connected to the door-releasing mechanism, having five holes into which pins may be placed. When the car is to dump at a certain place the man in charge puts a pin in the hole corresponding to the dumping point, and the car goes ahead until this pin strikes the tripping device, when the plate is moved and the door released. The weight of the ore tending to slide down the 55° bottom of the car opens the door, the ore slides out, and the door swings back into place. The motion of the rope is then reversed and the car hauled back, while the other car is hauled forward. The position of the pin need only be changed when the dumping place is to be changed. The car dumps from one side only and the bottom slopes only in that direction. The ends of

the part containing the ore are also sloped. The entire body is of wood, strongly framed and tied together, and is lined with plate; it is supported by two rollers on each of two 4-wheel steel trucks, each of these trucks being held to the car body by a pin, so that the car can turn fairly sharp curves. A minor point to be noted is that the hinges on the door of the car are turned inward, so that the center of gravity of the door is such that it automatically closes itself. An end elevation of this car is shown in Fig. 4.

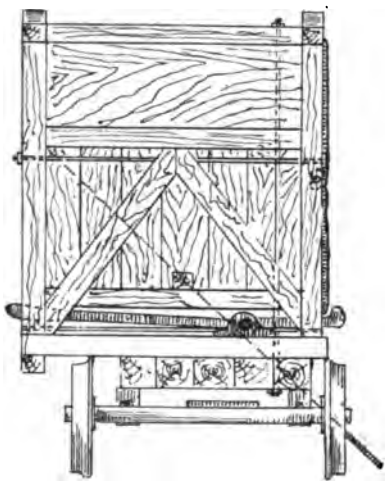

FIG. 4.

COAL HANDLING.

The large quantities of coal needed in mining operations make the problem of the handling of this mineral like that of ore handling, in that it must be done as economically as possible. The coal is delivered at the mines in railroad cars at one or several points, according to the number and position of the shafts and the buildings associated with them. From these centers it is brought, by animal or mechanical haulage, in small iron cars to the points where it is to be used.

In 1897 the Tamarack Mining Company built a shed of wood and iron to hold about 50,000 tons of coal, some 12 miles, by rail, from the mine. This shed is 428 ft. along the lake, 175 ft. wide and 38 ft. to the top of the tracks running across it. The coal is delivered by boats, from which it is raised mechanically to the top of one or more of five movable platforms carrying the hoisting machinery. The cars are run onto these platforms, loaded, and run back on one of a series of tracks across the shed, to be dumped at the particular spot desired.

In 1898 this storage plant was enlarged by the addition, at one end, of an uncovered flooring of heavy plank, on either side of which, about 165 ft. apart, are steel trestles consisting of light built-up supports carrying girders, somewhat on the style of the construction at the higher points of the elevated railroads in New

York City. On these trestles run small 8-wheel trucks, one for each end of light girders across the flooring. These girders, two in number, carry trucks on which the cars, 1½ tons capacity, are run from the loading platforms; the combination of the longitudinal motion of the girder with the transverse motion of the car permits any point to be selected for unloading. The movable girders project about 35 ft. beyond the trestle on the landward side, but end at the trestle on the lakeward side. There is a difference of 3 feet in level between the tops of the trestles, giving a grade in favor of the loaded cars; the same slope is given to the tracks in the shed.

The five loading platforms, or "towers," consist each of a rectangular steel framework and run on a track along the lakeward side of the shed and flooring. The machinery is all run by steam from a pipe, fastened to the trestle and the side of the shed, which has valves to which the apparatus on the towers may be connected. These valves are alternately 6 feet and 18 feet apart, so that a number of boats of any length can be unloaded simultaneously.* Three towers work at the shed, two at the trestle. The boiler plant is at about the middle of the line of piping. The stock piles built on the planking are loaded by steam shovels into railroad cars, just as iron ore is loaded under similar circumstances.

MISCELLANEOUS.

The electric current for the surface and underground haulage at the Lake Angeline Mine is supplied by a Thomson-Houston 500-volt, 10 per cent. over-compound, bipolar generator, belted to an Allis Corliss engine, and running at a speed of 900 R. P. M. The switchboard, of varnished plank, carries a fuse-box, a circuit breaker, a Weston voltmeter, a T.-H. current indicator reading up to 180 ampères, a double-pole switch, and a field rheostat to which a small voltmeter is attached. The turn-switch and fuse for the lamps in the building are also on this board. Beside the electric apparatus the room contains an air-compressor, and the constant motion hoist for the Lake Shaft.

The generating plant at the Lake Shaft of the Cleveland Iron Mining Co. is similarly situated with respect to the compressor and hoist for that shaft. The generator is a 4-pole General Elec-

*Hatches are always 24 ft. center to center.

tric Co. machine, rated capacity 420 ampères, 220 volts at no load to 240 volts at full load, and runs at 660 R. P. M. Although it is in a very unfavorable position, between two windows through which dusty winds blow directly upon it, it was said that no trouble had been experienced from grit in the bearings, and the commutator, running under carbon brushes, was in fine condition after three years' service. The dynamo is belted to the fly-wheel of an Allis Corliss engine. The switchboard is of the skeleton type, of varnished hardwood, and supports the following pieces of apparatus starting at the upper left-hand corner: a G. E. C. Type *B* lightning arrester; a G. E. C. 300- to 500-ampère circuit breaker; a Weston station voltmeter, 0 to 250 volts, illuminated by a lamp at its left side; a Weston station ammeter with a lamp at its right side; a large double-pole dynamo switch, flanked by a single-pole knife switch, for each level, on either side; a field rheostat; several small lamp switches; and two switches for changing the signal bells from the main circuits to battery circuits, or *vice versa*. At the time of visiting the ammeter showed a steady load of 75 ampères, due to lamps, leaks, etc., which frequently rose to 300 or 400 when the locomotives were in operation.

In the cellar of the engine house at the West Vulcan Mine is an open feed-water heater, in which the feed-water for the boilers is

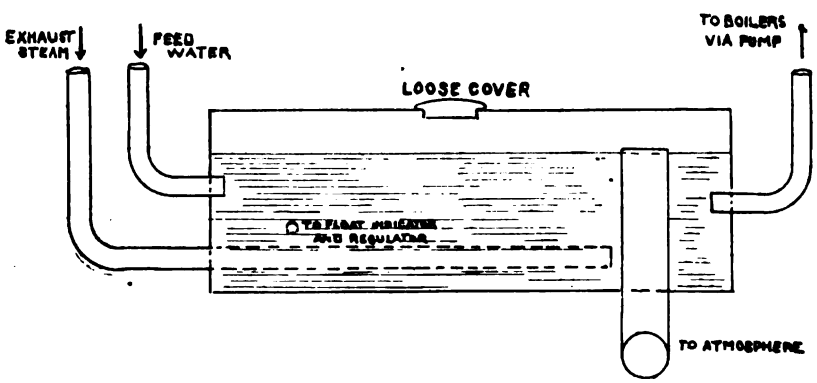

FIG. 5.

heated by the exhaust steam from the engines above blowing through it. The method of arranging the opening to the atmosphere is due to Mr. Roberts, the boss mechanic, and apparently has much to recommend it. In the ordinary open heater the open-

ing to the atmosphere is direct, not like an inverted siphon, so that the lighter steam has a continual tendency to escape into the air. See diagram, Fig. 5.

Another device, in use at this mine, arranged by Mr. Roberts, consists of a step-by-step motion, connected to the hammer of the signalling bell in the engine room, operating a hand on a clock face, thus registering the total number of strokes of the hammer per signal. The hand is brought back to zero by a spring released by a cord pulled by the engineer between signals.

At many of the Michigan mines the comfort of the men is looked after by the management. At several the "dry," or house to which the miners repair to change their clothing, possesses some excellent features. A typical example of this class of buildings is that at the Aragon Mine, of which a brief description follows. It is constructed of corrugated iron and wood, with lockers, in front of which are benches, against the walls. Along the middle of the room runs a wooden framework, into which nails are driven, on which the wet clothing is hung. Along each side of the framework, near the floor, runs a metal-lined trough to catch the drip from the clothing and the steam-heating pipes. The heating pipes, flanged and capped at their ends, are of large diameter and run between the uprights of the framework. The floor of the building is of wood.

The tally-boards in common use in engine rooms to keep account of the number of cars hoisted per day generally consist of rectangular tablets pierced with several columns of holes, usually three columns for each compartment of a shaft, the first column containing the numbers from 1 to 20, the second 20 and its multiples to 100, the third 100 and its multiples up to the maximum number of cars likely to be hoisted per day. Two pins are used in each column, following each other and moved alternately, thus: Pin A, 1, 3, 5, 7, etc.; pin B, 2, 4, 6, 8, etc., until the count is carried into the next column, when the pins in the first column are brought back to the top of it again.

At the Pewabic Mine, at the time of the writer's visit, four grades of ore were being taken out, differing in richness and in amount of phosphorus contained. An interesting feature of the ore in some parts of this mine is the rapid change in the phosphoric contents, one case being instanced to the writer by Captain Holland, in which the hematite varied from .009 % *P* to 1.150 % *P* within a distance

of three feet. A sample was taken from each car as it reached the surface, being put into one of four trays, according to the location of the workings, these samples being frequently analyzed to determine the grade of the ore mined. The cars were dumped, according to contents, into one of four bins. The quality of the ore, as determined by its location in the mine, was indicated by a number of broken pieces of wood laid on top of the car, the four grades being represented by three, two, one, or no sticks respectively.

With few exceptions the shafts of the copper mines are inclined, making necessary the use of skips. The great depth to which these shafts have been sunk and the danger to men raised and lowered in skips have caused the introduction of man-cars at several mines. These cars, when not in use, are suspended by chains above the mouth of the shaft. When men are to be carried the skip is removed, the man-car dropped upon the track and connected, and the men take their places and are carefully lowered. When the men are all up or down the man-car is taken off and the skip is re-connected. A 5-ton crane is used for each car; and five men are needed to do the work of changing. The transposition of the skip and the car has been accomplished in about one minute. Two long beams, each with a small wheel at its upper and lower ends, and tied together, form the frame-work of the car. On these are fastened horizontal benches seating three men each, and banisters, which also act as braces, formed of iron pipe. At the Quincy two sizes of man-cars are used—one holding twenty-four, the other thirty men. At the Atlantic the cars hold thirty men each. No satisfactory safety device is in use to stop the car in case the rope breaks.

BENDING MOMENTS IN SIMPLE BEAMS DUE TO WHEEL LOADS.

THOMAS J. BRERETON, C.E.

Whatever may be the outcome of the battle between wheel loads and equivalent uniform loading in the computations for trussed bridges, it is probable that many engineers will prefer to proportion their short girders and stringers by the non-uniform system,

and in the examination of existing structures, it is doubtful if any engineer would be contented with an investigation which neglected such a loading.

It is proposed in this brief paper to derive a formula for maximum bending moments due to non-uniform loads, and to illustrate some of its uses.

No apologies are necessary for what this paper offers in the way of repetition of that which may be found elsewhere. While the principles have been well stated in many works upon applied mechanics, the demonstrations are not so frequently met, and an attempt has been made here to derive a formula which may be as quickly applied as the well-known formulæ for uniform loadings.

PROBLEM I.—To find the equation of condition for the greatest bending moment at a given section for a given system of moving loads.

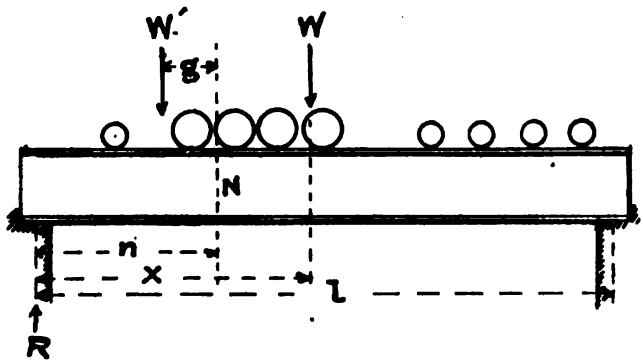

FIG. 1.

Let W be the entire weight of the system.

l the length of the girder, center to center of bearings.

n the distance of the given section, N, from the left abutment.

x the distance of the left abutment from the center of gravity of the loads.

W' the sum of the weights of all the loads to the left of the given section, N, conceived as acting at their center of gravity.

g the distance of the center of gravity of these loads from the given section, N.

R the reaction of the left abutment.

M_n the bending moment at the given section, N.

Then we have

$$R = \frac{W(l-x)}{l}$$

$$M_n = Rn - W'g = \frac{Wn(l-x)}{l} - W'g.$$

Suppose the system to advance a distance dx, so that no load passes off the structure, and no load passes the given section, N. x becomes $x - dx$, g becomes $g + dx$, and the consequent increment of M_n is

$$dM_n = \left(\frac{Wdx}{l}\right)n - W'dx.$$

Making

$$\frac{dM_n}{dx} = \frac{Wn}{l} - W' = 0$$

we have

$$\frac{W}{l} - \frac{W'}{n} = 0 \qquad (1)$$

or

$$\frac{W}{l} = \frac{W'}{n}.$$

That is the maximum bending moment due to a given system of moving loads at a given section, occurs when the sum of those loads on the left of the section divided by the distance to the left abutment, equals the entire weight of the system divided by the span, or in other words the average load per foot of span, equals the average load per foot on the left of the given section N.

If we consider equation (1), we shall observe that if $\frac{W}{l} > \frac{W'}{n}$ for any position of the load, $\frac{W}{l} - \frac{W'}{n}$ will be positive, if $\frac{W}{l} < \frac{W'}{n}$ the difference will be negative. Now the only way that any change can occur in the value of W', is for one of the wheel loads to pass N, when therefore that load passes N which alters the sign of the expression $\frac{W}{l} - \frac{W'}{n}$, its value has passed zero, and the condition for a maximum has been fulfilled. We may observe, therefore, that the equation of condition for a maximum bending moment at a given section is fulfilled;

For one concentrated load, when that load is at the section.

For two loads, when the first one is at the section.

For a uniformly distributed load, the equation is plainly exactly satisfied when the uniform load covers the entire span, and at no other time. Hence for a uniform load, the maximum bending moment at any section occurs when the entire span is covered.

For any system of concentrated loads, such as locomotive wheel loads, there may be more than one position of the loads which will satisfy the equation. The greatest of these maxima must be obtained.

The nearer the center of gravity of the entire system approaches the given section, evidently the greater will be the moment due to a load at that section. Also, of two or more sets of wheel loads which could come upon the girder, that one will give the greatest moment which produces the largest concentration of weight immediately to the right of the given section.

On this principle, the nearest wheel load to the left of the center of gravity of the entire system which can come upon the given section, all the wheels remaining upon the girder, will give the greatest possible moment at that section for that system of loads. We can determine only by trial which of several sets of wheels will give largest moment.

PROBLEM II.—To find the critical section of a girder, under a given system of loads.

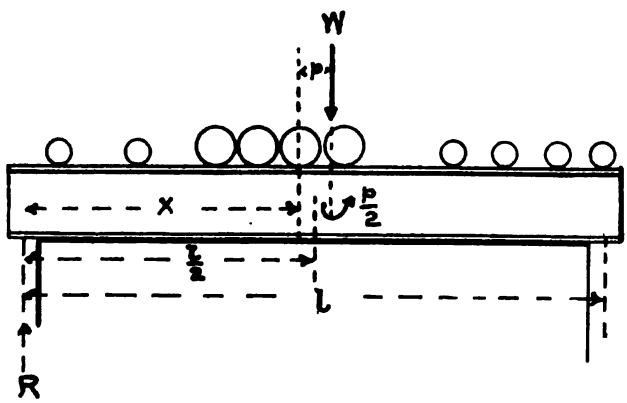

FIG. 2.

The greatest possible bending moment at any section of any girder due to any given system of moving loads, as shown above, will occur under a load as near as may be to the center of gravity of the system, the entire system remaining on the span.

When the center of gravity is near mid-span, it is evident that the greatest possible bending moment in the girder will occur.

Referring to Fig. 2, let

p be the distance from the center of gravity of the system of loads to the wheel on the left (the wheels moving to the left).

x the distance of the section under this wheel, at any time, from the left abutment.

R the reaction of the left abutment.

W' the sum of all loads to the left of this section.

W the weight of the entire system of loads.

g the distance of the center of gravity of loads to the left from section "X."

M_x the bending moment at section X.

Then $$R = \frac{W(l - x - p)}{l}.$$

The moment at X, $$M_x = \frac{W(lx - x^2 - px)}{l} - W'g \qquad (2)$$

differentiating, and placing first diff. coef. equal to zero,

$$\frac{dM_x}{dx} = \frac{W}{l}(l - 2x - p) = 0, \text{ whence } x = \frac{l - p}{2}. \qquad (3)$$

That is, "With any system of moving loads the greatest possible bending moment in a simple beam occurs at a section so located that the distance between it and the center of gravity of the system of loads is bisected by the center of the span." (See Merriman's "Mechanics of Materials," Advanced Problem No. 206.)

Replacing x in equation (2) by its value from equation (3) and reducing, we obtain

$$M = \frac{W}{l} \times \frac{(l - p)^2}{4} - W'g. \qquad (4)$$

Suppose that the system consists of one wheel moving over the beam p becomes 0, W' becomes 0, and we have

$$x = \frac{l}{2} \qquad (5)$$

$$M = \frac{Wl}{4} \qquad (6)$$

That is, when the girder is so short that only one wheel can come upon it at a time, the critical section occurs at mid-span, and equation (6) gives the well known value of the greatest moment.

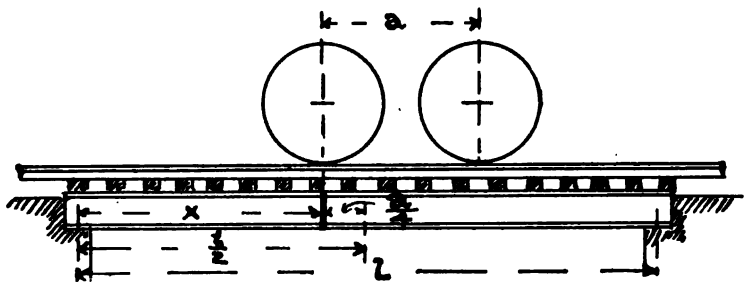

FIG. 3.

Suppose the system to consist of two equal loads, at a distance "a" apart, then p becomes $\frac{a}{2}$, W' becomes 0, and we have

$$x = \frac{l}{2} - \frac{a}{4} \tag{7}$$

$$M = \frac{W}{l}\left\{\frac{2l - a}{4}\right\}^2 \tag{8}$$

According to equation (7), the greatest bending moment caused by two equal loads rolling over a simple beam, occurs at a section distant $\frac{1}{4}a$ from the center of the beam, "a" being the distance between the loads. The value of the maximum bending moment is given in equation (8).

If the system of moving loads is one uniformly distributed over the girder, then

$$p = O,\ W'g \text{ becomes } \frac{W}{2} \times \frac{l}{4}, \text{ and we have, } x = \frac{l}{2}, \tag{9}$$

$$M = \frac{Wl}{4} - \frac{Wl}{8} = \frac{Wl}{8}, \tag{10}$$

or the critical section occurs at mid-span, and equation (10) gives the well-known value of the moment.

Equation (2) is for all practical purposes the equation of a parabola, with the origin of coördinates at the left abutment.

Let the line AB represent the length of the span, at a distance of $\frac{l-p}{2}$ from the left abutment lay off the greatest bending mo-

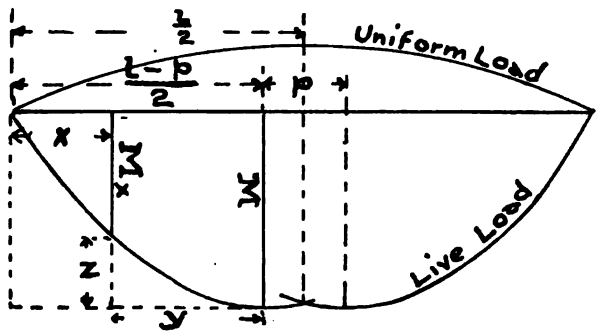

FIG. 4.

ment, M, as an ordinate. The greatest bending moment at any other point, due to this system of loads may then be found as follows:

Assume the equation of a parabola referred to its apex,

$$y^2 = 2tz. \tag{11}$$

Then, when

$$y = \frac{l-p}{2},\ z = M.\ \therefore\ \frac{(l-p)^2}{4} = 2tM,\ \text{whence}\ 2t = \frac{(l-p)^2}{4M},$$

substituting this in equation (10), we have,

$$y^2 = \frac{(l-p)^2}{4M}z,\ \text{and}\ z = \frac{4My^2}{(l-p)^2},$$

substituting for y its value, $\frac{l-p}{2} - x$, and reducing, we have,

$$z = M\left(1 - \frac{2x}{(l-p)}\right)^2.$$

Whence

$$M_x = M - M\left(1 - \frac{2x}{l-p}\right)^2 \tag{12}$$

where M_x is the greatest bending moment at a section distant "x" from the left abutment, due to this particular system of loads. The distance x must be such that none of the loads of the system have passed off the girder.

When $x = 0$, $M_x = 0$, for any system, and when

$$x = \frac{l-p}{2},\ M_x = M.$$

DIAGRAM OF WHEEL LOADS AND TABLE OF MOMENTS P.R.R. TYPICAL FREIGHT ENGINE.

200	192	177	162	147	132	124	116	108	100	92	77	62	47	32	24	16	8	1
8	23	38	53	68	76	84	92	100	108	123	138	153	168	176	184	192	200	2
3	8	4.5	4.5	4.5	11.5	5	5.5	5	8	8	4.5	4.5	4.5	11.5	5	5.5	5	3
4	8.0	12.5	17.0	21.5	33.0	38.0	43.5	48.5	56.5	64.5	69.0	73.5	78.0	89.5	84.5	100.0	105.0	4
5	105.0	97.0	92.5	88.0	83.5	72.0	67.0	61.5	56.5	48.5	40.5	36.0	31.5	27.0	15.5	10.5	5.0	5
6	120.0	307.5	562.5	885.0	1149.0	1453.0	1801.0	2189.0	2641.0	3608.5	4093.5	4746.0	5016.0	7632.0	8388.0	9188.0	10028.0	6
7	64.0	67.5	202.5	405.0	605.0	845.0	1129.0	1453.0	1841.0	2688.5	3603.5	4698.0	5636.0	6288.0	6980.0	7716.0	8492.0	7
8	167.5	67.5	67.5	202.5	366.5	570.5	818.5	1106.5	1458.5	2238.5	3086.5	4001.0	4983.5	5599.5	6235.5	6955.5	7695.5	8
9	338.5	202.5	67.5	67.5	195.5	363.5	575.5	827.5	1143.5	1856.0	2636.0	3483.5	4398.5	4978.5	5598.5	6262.5	6966.5	9
10	577.0	405.0	202.5	67.5	92.0	224.0	400.0	616.0	896.0	1541.0	2253.5	3033.5	3881.0	4425.5	5009.0	5637.0	6305.0	10
11	1359.0	1095.0	720.0	412.5	172.5	40.0	124.0	248.0	436.0	908.5	1498.5	2858.0	2731.0	3183.0	3679.0	4211.0	4787.0	11
12	1739.0	1435.0	985.0	602.5	287.5	40.0	44.0	128.0	276.0	673.5	1138.5	1671.0	2271.0	2683.0	3135.0	3631.0	4167.0	12
13	2201.0	1853.0	1320.5	853.5	458.0	128.0	44.0	48.0	144.0	453.0	844.5	1291.5	1809.0	2177.0	2585.0	3037.0	3529.0	13
14	2661.0	2273.0	1665.5	1125.5	653.0	248.0	124.0	40.0	64.0	304.0	611.5	986.5	1429.0	1757.0	2125.0	2537.0	2983.0	14
15	3461.0	3009.0	2281.5	1621.5	1029.0	584.0	316.0	168.0	64.0	184.0	367.5	682.5	885.0	1149.0	1453.0	1801.0	2183.0	15
16	4325.0	3809.0	2961.5	2181.5	1463.0	824.0	572.0	360.0	192.0	64.0	67.5	282.5	465.0	605.0	845.0	1123.0	1453.0	16
17	4878.5	4326.5	3411.5	2564.0	1784.0	1071.5	783.5	535.5	331.5	167.5	67.5	67.5	282.5	366.5	570.5	818.5	1106.5	17
18	5499.5	4911.5	3929.0	3014.0	2166.5	1386.5	1062.5	778.5	538.5	338.5	202.5	67.5	67.5	195.5	363.5	575.5	827.5	18
19	6188.0	5564.5	4514.0	3591.5	2616.5	1769.0	1409.0	1058.0	813.0	577.0	405.0	202.5	67.5	92.0	224.0	400.0	616.0	19
20	8120.0	7404.0	6181.5	5036.5	3939.0	2918.0	2467.0	2055.5	1687.0	1353.0	1095.0	720.0	412.5	172.5	40.0	124.0	248.0	20
21	8972.0	8244.0	6946.5	5716.5	4554.0	3453.0	2967.0	2516.0	2107.0	1739.0	1435.0	985.0	602.5	287.5	40.0	44.0	128.0	21
22	10012.0	9212.0	7832.0	6513.5	5274.5	4097.0	3564.0	3065.0	2613.0	2201.0	1853.0	1320.5	853.5	458.0	128.0	44.0	40.0	22
23	10972.0	10132.0	8677.0	7289.5	5969.5	4717.0	4141.0	3605.0	3113.0	2661.0	2273.0	1665.5	1125.5	653.0	248.0	124.0	40.0	23

Lines 1 & 2 Give Total Weight Summation for one Side, From Right and Left Respectively. Thousands of Pounds.
Line 3 Gives Wheel spacing; and loads for one Side. Lines 4 & 5 Give summation of Wheel spaces from Left & Right respectively.
Lines 6 to 23 Give Summation of Moments, in thousands of pound-Feet, to Right and Left about Wheel immediately above heavy vertical in stepped line.

It is thought that by means of equations (3) and (4), the critical section and greatest bending moment in a simple beam may be found with ease, and by means of equation (12), plate girder problems may be readily solved.

In this connection it may be observed that since the area of flange section is proportional to the bending moment, we may write

$$A_x = A - A\left(1 - \frac{2x}{l-p}\right)^2 \qquad (13)$$

Where A_x is the net flange area at a distance x from the left abutment, and A is the net flange area at the critical section.

The table of moments which appears above, is constructed in a similar manner to those which are in general use among bridge computers.

By means of this table it is easy to take out the value of "p" for any number of these wheel loads which could come upon a girder.

Example :—It is required to find the value of p for a typical P. R. R. freight engine.

In line 6 of the table we find 2189 as the summation of moments about wheel No. 1. In line 8, we find 100 the summation of wheel loads from same point.

The distance from wheel No. 1 to the center of gravity will be

$$\frac{2189}{100} = 21.89,$$

From line 4, we find the distance to wheel No. 5 is 21.5, hence p is $21.89 - 21.5 = 0.39$, and for this system, when all upon the girder, the maximum bending moment will be under wheel 5. Only by trial could it be known that for any particular girder some other set of these loads would not produce a greater maximum bending moment.

Example 2 :—It is required to find the value of p for the first 5 wheels of the same engine.

In line 6 we find 885 as the summation of moments from 1 to 5. And in line 2, 68 the summation of wheel loads to the same point. $\frac{885}{68} = 13.02$, the distance from wheel 1 to the center of gravity of these loads. From wheel 1 to wheel 3 is 12.5, and $13.02 - 12.5 = 0.52 = p$, and the maximum bending moment for that system will occur under wheel 3.

To demonstrate this method of finding the center of gravity of any number of wheel loads, we have the principle that the sum of the moments of all the wheels in the system about the center of gravity is zero.

Let W', W'', W''', W'''', etc., be a system of wheel loads, the distances apart of which are a, b, c, etc., respectively. Let x be the distance of W' from the center of gravity. Then $W'x + W''(x-a) + W'''(x-a-b) + W''''(x-a-b-c) + \text{etc.} = 0$. $W'x + W''x + W'''x + W''''x + \text{etc.} = W''a + W'''(a+b) + W''''(a+b+c) + \text{etc.}$

$$x = \frac{W''a + W'''(a+b) + W''''(a+b+c) + \text{etc.}}{W' + W'' + W''' + W'''' + \text{etc.}}$$

or the distance from the first wheel in any system of loads to the center of gravity of the system is the sum of the moments of all the wheel loads taken about wheel 1, divided by the total weight of the system.

Example 3: — It is required to find the critical section and the greatest possible bending moment, due to the above wheel loads in a girder 30 feet from center to center of bearings.

The first 5 wheels can come upon the girder at one time.

From example 2, $p = 0.52$,

$$\therefore \quad x = \frac{l-p}{2} = \frac{30 - 0.52}{2} = \frac{29.48}{2} = 14.74 \text{ feet,}$$

the distance from the left abutment to the critical section, and the greatest moment at that point is

$$M = \frac{W}{l}\left(\frac{l-p}{2}\right)^2 - W'g.$$

Giving the above values, we have $M = 68/30 \times (14.74) - 167.5$ (The last quantity is taken from line 8, as the sum of moments of wheels 1 and 2 about wheel 3.) Solving, we have $M = 325.70$ thousands of pound-feet.

Suppose wheel 1 to have passed off the girder, and wheel 6 not yet to have come on. We have $p = 2.25$, and

$$\frac{l-p}{2} = \frac{30 - 2.25}{2} = \frac{27.75}{2} = 13.875,$$

the distance to the second driver from the left abutment when the maximum bending moment for this set of wheels occurs, and hence

the critical section. The value of the bending moment is, 60/30 (13.875) — 67.5 = 317.54 thousands of pound-feet.

Suppose wheel 6 to have come on the structure, $p = 0.78$, the critical section occurs under the third driver, No. 4 of the table, at a distance of 14.61 ft. from the left abutment, and the moment is 307 thousand pound-feet.

The first combination is thus found to give the greatest bending moment in the girder.

If the girder is 3 ft. deep, the flange stress is $\frac{325,700}{3} = 108,567$ pounds, and if the allowable stress is 10,000 lbs. per square inch, we shall have 10.86 square inch net area of flange section for live load. To this must be added the area required by the dead load. To find the net area required by the live load at any other point, we have from equation (13) $A_x = 10.86 - 10.86\,(1 - 2x/29.48)^3$, for $x = 5$, $A_x = 6.06$ for $x = 10$, $A_x = 9.68$, and for $x = 15$, $A_x = 10.859$. or at mid-span slightly less area is required than at the critical section. To each of the above areas must be added the area due to dead load.

By a simple transformation of equation (13), we obtain

$$x = \frac{l-p}{2}\left(1 - \sqrt{\frac{a}{A}}\right) \qquad (14)$$

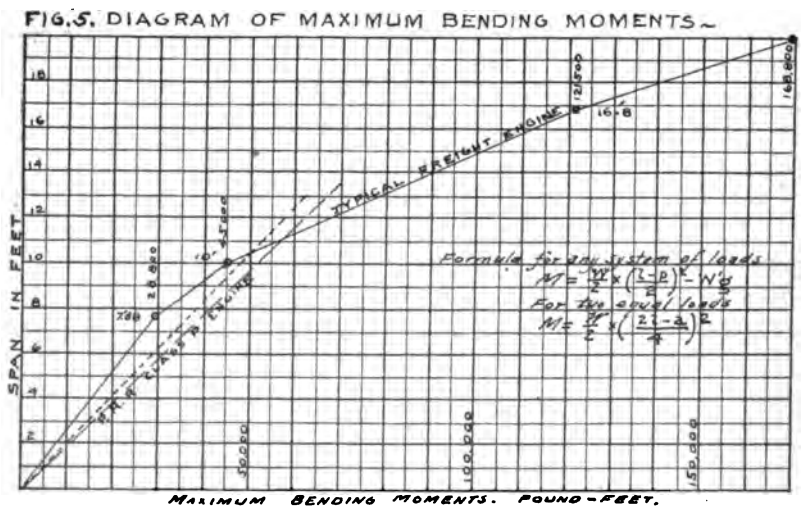
FIG. 5. DIAGRAM OF MAXIMUM BENDING MOMENTS.
SPAN IN FEET
TYPICAL FREIGHT ENGINE
Formula for any system of loads
For the equal loads
MAXIMUM BENDING MOMENTS. POUND-FEET.

FIG. 5.

In this equation A is the net area required by the live and dead loads at the critical section, a is the area of the cover plate or plates so that $A - a$ is the net area required at the point distant x from the left abutment. The theoretical length of the cover plate ending at x is then $l - 2x$. The cover plate is always extended in each direction, at least two rivet spaces more than this length.

Assume equation (4).

$$M = \frac{W}{l}\left(\frac{l-p}{2}\right)^2 - W'g.$$

If the system of wheel loads remains constant and l varies, p will remain constant also, and M will vary directly as l. Equation (4) is, in other words, that of a straight line, when W and W' remain constant.

Referring to the Engine diagram in the table of moments, it will be evident that for spans too short for two wheels to come upon at once, one driving wheel will cause the greatest bending moment, and its value will be, $M' = \frac{W'l}{4}$.

Likewise there will be some length of span where two driving wheels cause the greatest bending moment, and its value will be

$$M' = \frac{W''}{l}\left(\frac{2l-a}{4}\right)^2.$$

There must be some intermediate span where $M' = M''$, and we may find the length of this span by placing

$$\frac{W'l}{4} = \frac{W''}{l}\left(\frac{2l-a}{4}\right)^2$$

and solving for l.

The diagram shown in Fig. 5 has been plotted from such a set of computations, and shows graphically the greatest bending moments in pound-feet for the loads shown for spans up to 20 feet. The diagram could be extended as far as desirable, say up to the limiting span for plate girders.

NOTES ON TELEGRAPHY AND TELEPHONY.

By W. H. FREEDMAN, E.E.

(Continued from page 65, Vol. XX.)

Telegraphic Circuits.

Telegraphic circuits may be arranged in one of three different ways for the transmission of signals:—

1. The generator may be normally disconnected from the line and signals may be transmitted by alternately inserting the generator *into* and withdrawing it *from* the circuit, so as to cause a current to flow for the proper length of time to form the signals. This constitutes an *open-circuit* system.

2. The generator may be normally in connection with the line, thereby causing a current to continually traverse the circuit, and signals may be transmitted by alternately *breaking* and *closing* the circuit. This forms a closed-circuit system.

3. The generator may be normally in connection with the line as in a closed-circuit system; the signals, however, being transmitted by *first interrupting* the current at the sending point and then closing the circuit at properly timed intervals, thus permitting the current from the generator to traverse the line and receiving instruments as in the open-circuit system. This is the American modification of the closed-circuit system.

Earth Return.—Whichever plan may be employed only one line wire is used wherever possible, the earth completing the circuit. The connection of the earth is made by means of ground-plates, which may be of sheet copper one-sixteenth of an inch thick and having an area of 36 by 48 inches. Plates of galvanized iron are often used instead of copper, being cheaper and answering the purpose perfectly well. The ground-plates should be buried in moist earth in a vertical position. In many cases an available substitute may be found by attaching the terminal of the line, by soldering or otherwise, to a pipe which forms a part of an extensive network of gas or water pipes buried in the earth, the large surface of which insures a most excellent conducting connection. It is advisable, wherever possible, to attach the wire to both gas and water pipes. When the wire is thus connected it is necessary to observe the precaution of soldering it to the pipe outside the

meter. The joint where the connecting wire is soldered to the ground plate should be coated with insulating material to prevent corrosion by electrolysis which might otherwise take place.

If circumstances render it necessary to bury a ground-plate in badly conducting soil (as for instance, where it is rocky, sandy or gravelly, without sufficient moisture), a pit should be dug and filled with scrap tin or other waste metals laid in contact with the plate, and the surface drainage and discharge from water pipes should be led into it.

The resistance of the earth return is practically independent of the length of the circuit, so that as the lines are longer the earth resistance becomes of less and less importance. The earth here, as regards the resistance it interposes in the path of the current, acts similar to a medium of unlimited extent. For, if we have two spherical electrodes placed in a homogeneous conducting medium of infinite extent and at a distance from each other many times their diameter, it can be shown mathematically* that the resistance between them does not vary with their distance apart but depends only on the radius of the spheres and the specific resistance of the medium.

The earth as a ground return imperfectly fulfils these conditions. Increasing the area and improving the contacts of the earth plates lowers the resistance. Dr. Louis Bell† places the resistance of a ground return between buried plates under favorable conditions at about 75 to 80 ohms.

The advantages of an earth return may be stated briefly as follows:—

1. It saves the expense of a return wire.

2. On long lines it practically halves the resistance of the line. This allows the generator to be of corresponding lower output to give the same current or the same generator will operate a circuit of double the length. In some regions, however, on account of the geological character of the ground its specific resistance would prohibit the use of the earth return. Such instances have occurred in the coal regions of Pennsylvania and in certain portions of New Hampshire and Vermont.

3. It allows the same pole line to carry twice as many circuits or for the same number of circuits materially decreases the cost of

* Electricity and Magnetism, by W. T. A. Emtage, second edition, page 124.

† The Earth as a Conductor, *American Electrician*, February, 1896.

erection, stringing, line fixtures, labor, inspection and repairs. This is also true if the circuits are laid in an underground conduit.

The employment of the earth return is open to two objections, which, however, only in exceptional cases counterbalance the saving effected by its use:—

1. The line must be more carefully put up so as to maintain a high insulation resistance in order to prevent leakage to the ground. This increases the cost of erection per line wire.

2. Earth currents may actually cause a sufficient difference of potential between the ground plates as to interfere with the proper transmission of signals on the line. These may be due to magnetic storms and be only temporary or they may be due to proximity to some grounded power or railway circuit and, therefore, of a more or less permanent nature.

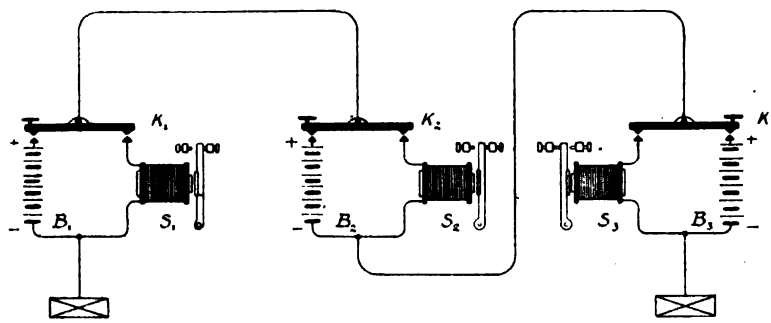

FIG. 6. Diagram of Open Circuit System.

The Open Circuit.—A telegraph line arranged upon the open circuit plan is illustrated in Fig. 6. Two terminal stations and an intermediate one are shown, each having a battery, a transmitting key and a receiving instrument. The circuit of the line divides at each key into two branches, of which only one can be closed at a time. One branch includes the battery only, and the other the receiving instrument only. The latter branch is normally in connection with the circuit of the line. If a signal is to be sent, the key is depressed by the operator, so as to establish the connection of the line with his battery, having first broken it with the instrument. A current from the battery will now flow through his key and over the line passing through the instrument contacts of the keys and through the receiving instruments of the other stations, the circuit being completed through the ground plates and the intervening

mass of earth. In this arrangement, therefore, each station transmits signals by inserting its own battery at timed intervals into a circuit of conductors which is already complete.

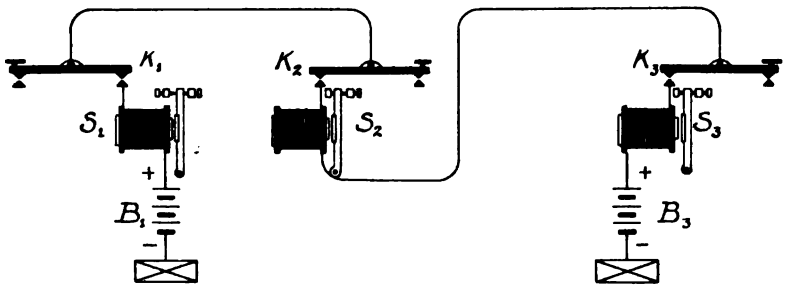

FIG. 7. Diagram of Closed Circuit System.

The Closed Circuit.—Fig. 7 illustrates the closed-circuit plan, properly so called. In this the cells of the batteries or the generators are always in the circuit, which passes normally through the rear or breaking contact of the keys and through the receiving instruments *at all stations*. By depressing the key at any station the current of the entire line is interrupted and a signal is simultaneously given by all the receiving instruments. In this system each station does not necessarily require a separate generator.

American Modification of the Closed Circuit.—The standard arrangement employed in the United States, Canada and Mexico

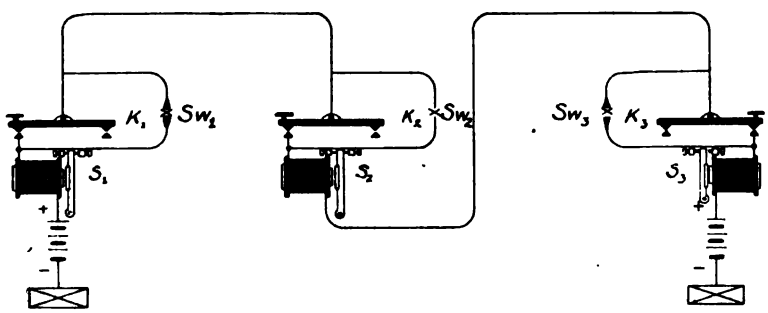

FIG. 8. Diagram of American Modification of the Closed Circuit System.

is shown diagrammatically in Fig. 8. It differs from the last described in that the circuit does not normally pass through the key at all, but through a switch or special circuit-closer beside it, which as a matter of convenience is in practice usually mounted upon

the key, though shown separately in the diagram. To transmit a signal according to this plan the circuit is first broken by opening the switch and the signals are then made by depressing the key so as to close the circuit at timed intervals upon its front contact point. As in the last case, the alternate opening and closing of the circuit at one station affects all the receiving instruments alike.

Relative Advantages of the Different Plans.—The points to be considered in regard to the open-circuit system are as follows:—

1. Energy need only be supplied to the line while a message is being sent. When batteries are employed, for example, a considerable decrease in the quantity of chemicals consumed in a given time would therefore result. This consideration, however, loses weight with lines in constant use.

2. The circuit being closed on the down stroke of the key the signals are firmer and purer, for if made by the up stroke, the actual making of the contacts depends upon the spring of the key, the action of which is more or less uncertain. The length of contact can also be better timed and speed of working increased.

3. The receiving instrument at the sending station is cut out of circuit by the action of the key, thus reducing the total resistance. This, however, is more than counterbalanced by the fact that the sender can therefore not tell whether the line is in perfect working order to perfectly transmit his message. He must wait until the receiving station replies, or fails to reply, or else be provided with an additional tell-tale instrument which is always in circuit.

4. The open-circuit plan, on the other hand, requires *each* station to have a battery or generator large enough to operate the line, as the one at the particular station sending is the only one furnishing current for any given message. A line having four stations, for example, would require four times the generator output on the open than on the closed-circuit plan. In the case of long circuits this greatly increases the first cost. The use of primary batteries except at terminal stations is compulsory as the cost of the dynamos necessary under these conditions would be prohibitive and storage batteries would need facilities for recharging.

In regard to closed-circuit working we find:—

1. Although it requires a continual supply of energy to the line, yet the generators can all be placed at the terminal stations, where they can receive more skilled attention and care. Also by this concentration the expense of maintenance will be decreased, and

dynamos and storage batteries could be used to the exclusion of primary batteries and numbers of lines could be operated in parallel from the same set of generators.

2. The receiving instrument at the sending station tells at once by its action whether the line is in perfect order or not. This often prevents unnecessary delay and annoyance, without the use of additiona truments.

3. The closed-circuit plan, however, closes the circuit on the up stroke of the key, and thus the signals are apt to suffer and the speed of working cannot be made so great.

The American modification of the closed-circuit system has all the advantages of the closed system proper, together with the purity of signals obtained in open-circuit working. Its only disadvantage is the continual consumption of energy when the line is idle.

Everything taken into consideration, the American system would necessarily be the one selected as soon as there are any number of stations on the same line, from point of first cost, as well as convenience, ease and speed of working. In case, however, of only two, or at most a few stations on the line, the selection of the system to be employed can only be decided upon after careful consideration in each particular instance.

Best Position of Generator in Circuit.—If the insulation of a line were absolutely perfect, the position of the generator in the circuit would be entirely immaterial. But all lines are ordinarily subject to more or less leakage throughout their length and the strength of the leakage current at any given point depends, of course, by Ohm's law, upon the resistance of this particular path and upon the difference of potential between this point of the line and the ground. The difference of potential between any point of the line and the ground is, in turn, dependent upon the position of the generator. For instance, let a certain closed circuit employ 100 volts to operate the instruments and its insulation be perfect. If the batteries are all at one end the potential will fall regularly and gradually from 100 volts at the battery end to zero at the other, and the average difference of potential between the line and the ground will be 50 volts. Should the batteries be equally divided and half placed at each end, one end will be 50 volts above and the other 50 volts below the potential of the earth and the average difference of potential between the line and the ground would then

be only 25 volts. If, now, the insulation is not perfect the leakage must be much less with the second arrangement of the batteries than the first. Theoretically, therefore, the batteries should be divided and distributed along the line from point to point in closed-circuit working, thereby decreasing the average difference of potential between the line and the ground without decreasing the electromotive force in the circuit proper.

Leakage besides representing a continual waste may also interfere with the proper working of the line. Suppose we have a leaky line of two stations, *A* and *B*, with all its batteries at *A*, but still enough current passing through the receiving instrument at *B* to make it respond. Breaking the circuit at *B* by opening the key will not reduce the current passing through the receiving instrument at *A* entirely to zero, for whatever leakage currents and escapes there were, must still exist and may even have increased due to changes of potential of the line and their present sum is the value of the current flowing through the instrument at *A*. This may still be of sufficient strength to keep the armature drawn up against the electromagnet and no signal is produced. In other words, the key at *B* does not produce the full variation in the current strength and this makes the proper adjustment of the receiving instrument more difficult even if at all possible. Opening the key at *A* reduces the current to zero and the instrument at *B* will respond. Therefore, with this arrangement the signals are received with much more difficulty at the station where the battery is situated than at the opposite end of the line. The remedy, of course, is to reduce the leakage, which, as we have seen, can be accomplished by distributing the batteries.

The usual arrangement of generators at each end is from the foregoing considerations obviously altogether preferable. In practice, however, comparatively short lines are often supplied with generators only at one end, while in rare instances, the generators are placed in the middle of the line only, thereby accomplishing the same result as placing half at each end. Very long lines are occasionally provided with an intermediate set, midway between the terminal generators.

TRANSMITTERS.

At the time of the construction of his first machine, Morse had not conceived the idea of the key now in use, the successful ma-

nipulation of which depends upon the skill of the operator, but supposed that the proper degree of accuracy could only be secured by automatic apparatus. His first method of automatic transmission consisted in using type, resembling saw teeth, set up in long frames and made to pass, by means of machinery, at a uniform rate, under a pivoted lever weighted at one end. As each of the projections of the type passed under a wedge-shaped tooth upon the lever, it raised that end of the lever and depressed the other causing a U-shaped piece of wire to dip into two mercury cups and by thus connecting them together, close the circuit.

Figure 9 represents the saw-teeth type. The tops of the narrow

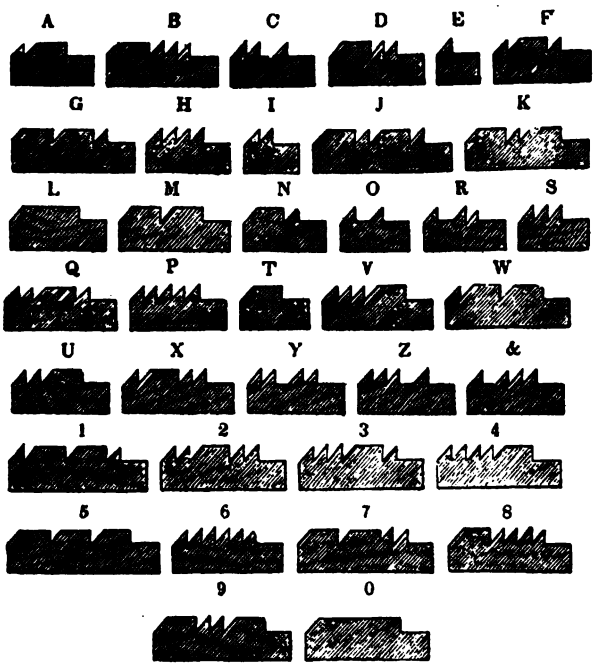

FIG. 9.

teeth correspond with the *dots* of the letters, and the long teeth with the *dashes*. The space at the end of a type corresponds with the short space between two letters.

Even after keys were employed to make and break the circuit, Morse was not fully convinced that this was the best method and devised several arrangements with the object of securing a simple

and a speedier method of transmission. One of these consisted of a metal plate *A*, Fig. 10, on which were raised pieces of metal

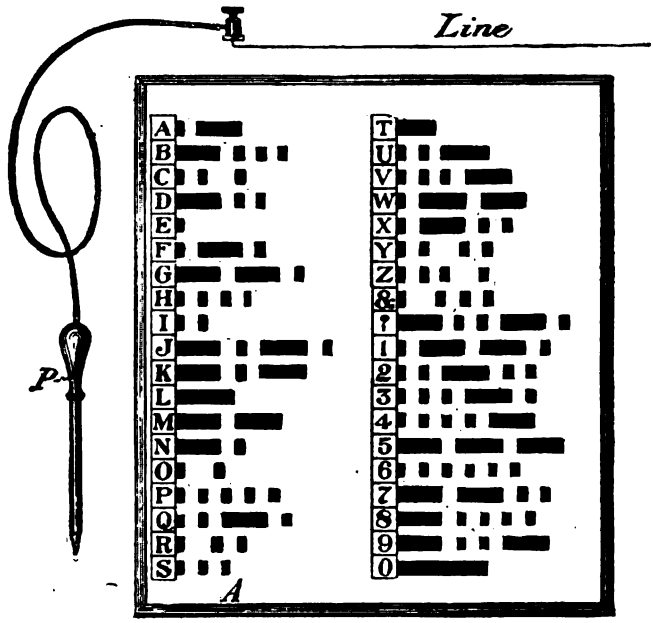

FIG. 10.

corresponding to the dots and dashes of the alphabet. The spaces between the raised pieces of metal were filled in with an insulating material to secure an even, plane surface. The battery was connected to the metal plate and a metal pointer *P*, having an insulated handle, was connected with the line. Consequently, when the pointer touched any one of the raised pieces of metal the circuit was completed. The operator held this pointer in his hand and drew it over the surface of a desired character, closing and opening the circuit, as he did so, in a manner to correspond to that letter.

The Morse Key.—The first style of key seems to have been of sheet metal, like a strap key, and when not used to signal its contact points were connected with each other by inserting a metallic wedge between them. The next step was to provide a separate switch to be able to short-circuit the contact points of the key and to mount the lever on trunnions. By combining the switch on the same base and continually reducing the mass of metal involved,

the key has passed by gradual stages from being crude and cumbersome to a light, compact affair weighing only several ounces. As made to-day it appears in many different forms, but not essentially differing in principle. Its essential portions consist of the lever, the finger-knob, the spring, the switch or circuit-closer, the platinum contact-points and the base. The lever, which was formally made of cast brass, is now more usually punched from sheet steel, which renders it not only stronger but of less weight and more easy to be manipulated with rapidity.

A pattern of key much used is shown in Fig. 11. The lever,

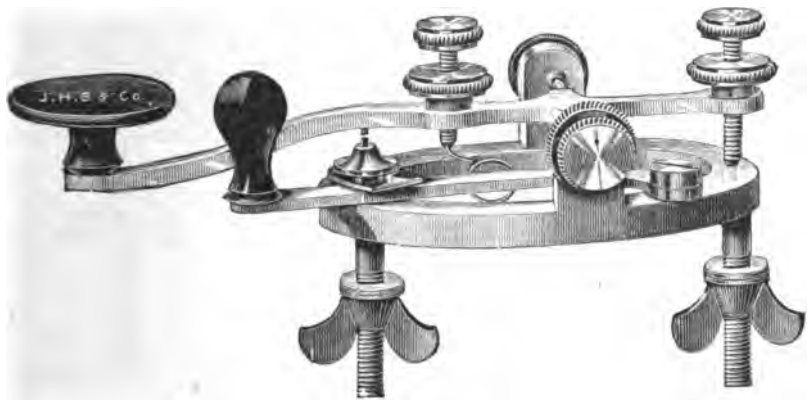

FIG. 11.

slightly curved, is provided with trunnions which turn between adjustable set-screws. The lever has a small reciprocating movement upon its axis, limited in one direction by the adjustable set-screw at the back, and in the other by a platinum contact-point inserted in a brass stud, which is insulated from the frame of the key. The finger-knob, usually of non-conducting material, enables the key to be conveniently depressed at pleasure by the finger of the operator. This action brings a platinum contact-point, inserted in the under side of the lever, into contact with the one above mentioned which forms a part of the anvil. One of the circuit-wires is clamped to the brass rod at the back by means of a clamp screw underneath the table, this rod being in metallic connection with the base. The other circuit-wire is attached by means of another clamp-screw to a similar brass rod at the front, connected with the anvil and insulated from the frame. When the key-lever is depressed, the circuit is consequently closed. When the pressure of

the finger is withdrawn, the adjustable spring beneath the lever, restores the latter to its normal position. The upward pressure of this spring is adjusted by means of its set-screw. When the key is not in use, the main circuit is closed by shoving the pivoted switch-lever into the recess formed between the lip of the anvil and the frame, thus closing the circuit, notwithstanding the separation of the contact-points.

Of late years other forms of keys have been much used, in which trunnions are dispensed with. One of these is shown in Fig. 12.

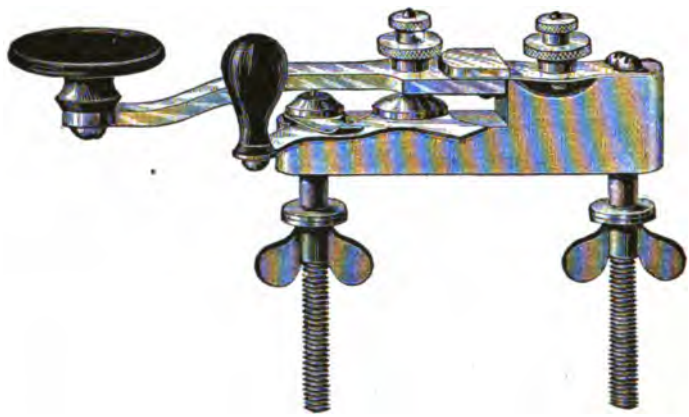

FIG. 12.

The lever is secured to a rearwardly extending flat steel spring, the opposite end of which is firmly fastened by screws to the base. An adjustable set-screw passes through a hole in the center of the spring and its nut may be set to bear upon its upper surface, thus enabling its flexibility to be regulated as desired. A second check-nut is capable of adjustment to regulate the stroke, or extent of vertical vibration of the key-lever.

In adjusting a key for work, the best result will usually be at-

FIG. 13.

tained by giving the lever a small movement with a moderate upward spring-pressure. Trunnion keys should be carefully adjusted, so as to prevent unnecessary lateral movement on the one hand, and unnecessary friction on the other. A trunnionless key, working upon knife-edged bearings, now very extensively used and known as the "Victor," is shown in Fig. 13. By this device, friction and weight are reduced to a minimum, while adjustment is rendered more convenient. This also shows a modification which is applicable to all keys and which consists in placing two binding-screws, one of which is insulated, upon the top of the base, to which the wire connections are made, thus avoiding the necessity of boring holes through the table, which is sometimes objectionable.

In Morse systems, that are used for transmitting more than one message at a time, the transmitters are not simple keys, but generally instruments whose levers are operated by electromagnets. These electromagnets are energized from a separate or local circuit, whose current is, however, made and broken by a simple Morse key. A full description of these examples of transmitters will be found under their respective systems.

European Keys.—The Morse key as used in the British telegraphs operating on the open-circuit plan is shown in Fig. 14. The line wire is connected with the central pivot. A spring keeps the front end of the key elevated when not in use, so that the line wire is in communication through the rear end of the key with the receiving instrument. Depressing the key breaks this communication, and, by putting the line wire in communication with the sending battery, transmits a current through the line.

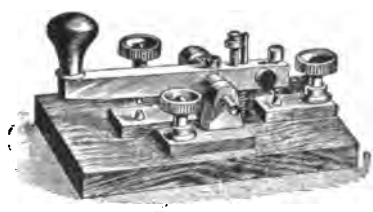

FIG. 14.

Siemens and Halske's magneto-induction key was at one time used in Europe and was intended for working a line on the Morse system by means of induced currents, dispensing altogether with the main batteries. This form of key is shown in perspective in Fig. 15. S and N are two rows of permanent bar magnets; the upper ones with their north ends and the lower ones with their south ends in contact with a heavy plate P of soft iron. The soft iron armature E is as long as the magnet system is wide, and is

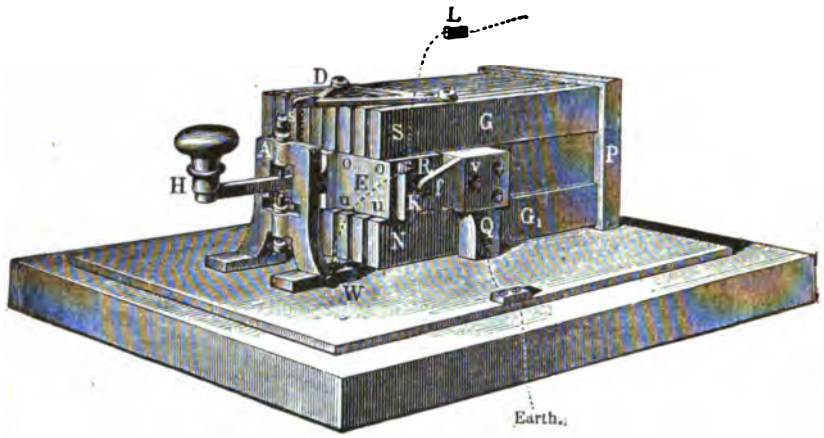

FIG. 15.

cut in deep longitudinal grooves, as is shown in Fig. 16. This is mounted upon two screw points between the poles of the magnet system and is capable of being oscillated by means of a handle, *H*. The play of the lever or handle *H* is limited by adjustable screws fixed in the frame *A*. The normal position of the key is shown in Fig. 16, and it is main tained in that position by the spiral spring *S*, attached to the triangle *D*. A coil of fine insulated wire is wound longitudinally in the grooves of the armature *E* and it is in this coil that the E. M. F.'s are induced by the motion of the key. When at rest in its normal position the lever strikes the upper set screw of the frame *A* and thereby short-circuits the coil in the armature. A polarized receiving instrument, the principles of which will be given later, must be used with this key.

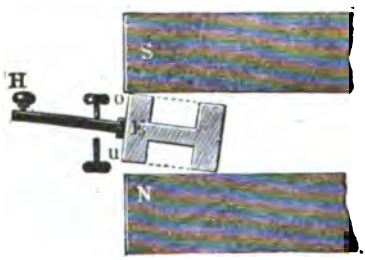

FIG. 16.

The needle telegraphs of Europe employing deflections to the right and to the left to form their code of signals require the current to be reversed. The key used in such systems is shown in plan in Fig. 17. *L* and *E* are two levers connected respectively with the line and with the earth. When they are not depressed they both rest against the upper bar *C*, which is connected with

the positive pole of the generator. Either lever can be depressed so as to come in contact with the bar *Z*, which is connected with the negative pole of the generator. The receiving instrument at the other end of the line is so connected that the depression of the left-hand key causes a deflection to the left, a depression of the right-hand key a deflection to the right.

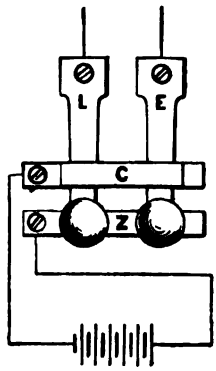

FIG. 17.

Various Transmitters.—In submarine cable work a double or tapper key, similar to the one used on the needle telegraphs of Europe, is employed. In dial and printing telegraphs, the pointer or the type wheel is brought to its proper position by a step-by-step device. For every impulse sent into the line the dial or type wheel moves one step. The proper number of impulses are sent by the depression of keys on a suitably arranged key-board. Various automatic transmitters exist by means of which the message is sent by the motion of a previously perforated strip of paper. The paper passes between two terminals of the main line, the circuit of which is completed when the terminals come in contact through the perforations and is broken when separated by the unperforated portions of the paper.

In the Wheatstone system the perforations of a moving strip of paper mechanically control the movements of the levers, which make contact between the line and the generator.

ABSTRACTS.

INDEX TO MINERALOGICAL ARTICLES WITH NOTES.

By

A. J. MOSES AND L. McI. LUQUER.

CONTINUED FROM PAGE 88, VOL. XX.

INDIVIDUAL SPECIES.

AGRICOLITE.—Frenzel.—*Min. Mitth.*, XVI., 523. Radiated aggregates of gray yellow to green color on bismuth ochre at Stamm Asser Mine, Graul, Saxony. Resembles wavellite.

ALBITE, from Lakous.—C. Viola.—*Min. Mitth.*, XV., 153.

ALTAITE, from Burma.—H. Louis.—*Min. Mag.*, XI., 215, 1897.

Occurs finely crystalline and very minutely disseminated with gold in the vein at Choukpazat Gold Mines. Analysis very close to accepted composition of altaite; but mineral appears to differ in being brittle instead of sectile and somewhat softer, perhaps due to its minute state of dissemination.—L. McI. L.

AMALGAM, from Chalanches (Isère) mine.—A. Lacroix.—*Bull. Soc. Min.*, XX., 233, 1897.

AMPHIBOLE und Sodalith aus dem Trachyt von Montesarito.—P. Franco.—*Zeit. f. Kryst.*, XXV., 328.

ANALCITE, see under Leucite.

ANDALUSITE.—Ueber Maltesit aus dem Östlichen Finland.—J. J. Sederholm.—*Geol. För. Förh.*, XVIII., 390; *Neues Jahrb. Min.*, 1898, I., 445, Ref. Variety of andalusite resembling chiastolite occurring in mica schist.

Manganandalusite von Vestanå.—H. Backström.—*Geol. För. Förh.*, XVIII., 386; *Neues Jahrb. Min.*, 1898, I., 444, Ref.

A variety of andalusite occurring in muscovite-quartzite of the Vestanå region, Sweden. Contains 6.9 per cent. Mn_2O_3, and differs in pleochroism from ordinary andalusite.

ANDORITE, identity with sundtite and webnerite—G. T. Prior and L. J. Spencer.—*Min. Mag.*, XI., 286, 1897.

Chemical composition $= 2PbS. Ag_2S. 3Sb_2S_3$. Krenner's determination the correct one for the species. Sundtite correct crystallographically, but wrong chemically. Webnerite incorrect crystallograpically, but right chemically.—L. McI. L.

ANORTHITE, Mineralogical Notes.—J. H. Pratt.—*Am. Jour. Sci.*, iv., V., 128, 1898. Occurs at Buck Creek, Clay Co., N. C. in nodules with olivine, forming a mass of forellenstein. Analysis is recorded.

APATITE, Die Formel des Apatits.—C. Rammelsberg.—*Neues Jahrb. Min.*, 1897, II., 38.

APOPHYLLITE, new occurrence in South Africa.—J. A. L. Henderson.—*Min. Mag.*, 1897, XI., 318.

Crystals (0.05–0.08 cm. in size) are translucent and nearly colorless or feebly yellowish, and occur in the "blue ground" of Jagersfontein, Orange Free State. Usual basal cleavage with pearly lustre observed and optical anomalies noted. Occurrence is remarkable on account of P [111] being the only form observed, and the crystals being embedded (apophyllite usually occurring encrusting matrix).—L. McI. L.

ARAGONIT von Sicilien und seine Structur.—C. Viola.—*Zeit. f. Kryst.*, XXVIII., 225.

ARSENIC from Akadanimura, Ohnogori, Japan.—Frenzel.—*Min. Mitth.*, XVI., 523. In rhombohedra nearly cubical or groups of these.

ASBESTOS and Asbestiform Minerals.—G. P. Merrill.—*Proc. U. S. Nat. Museum*, 1896, XVIII. (1895), 281–92.

As commercially used the name asbestos now covers four distinct minerals: tremolite or asbestos proper, serpentine (amianthus), anthophyllite and crocidolite. The fibrous structure of these minerals is in many cases secondary.—L. McI. L.

AURICHALCITE.—Auricalcite di Campiglia Marittima e Valdaspra.—G. d'Achiardi.—*Atti. dell. Soc. Tosc. di Sci. Nat.*, XVI., 1–15; *Neues Jahrb. Min.*, 1898, I., 439, Ref.

BARITE.—Zur Symmetrie der Krystalle.—J. Beckenkamp.—*Zeit. f. Kryst.*, XXVII., 583, XXVIII., 69–102.

After investigation of the geometrical and electrical properties of barite and by etching, author concludes that the structure of the barite crystal, *if thereby we mean the distribution of the molecules in space*, corresponds to rhombic hemihedry but the molecules are endowed with electric polarity.

BERYL.—Emeralds of Colombia, associated with anthracite and pyrophyllite.—A. Damour. *Bull. Soc. Min.*, 1897, XX., 183.

BERZELIITE.—Sodaberzeliit von Långban.—H. Sjögren.—Bull. Geol. Inst. Univ. Upsala, II., I., 3; *Neues Jahrb. Min.*, 1897, I., 447, Ref.

A berzeliite containing five per cent. of soda, orange yellow to fire red, usually compact but occasionally crystallized showing 211 and 110.

BIOTITE.—Eine neue Art der Zwillingsbildung des Biotits.—S. Uroschewitsch.—*Zeit. f. Kryst.*, XXIX., 278.

Dschepa in Servia furnishes fairly large well formed crystals, frequently twinned by a new law therefore called "Servian twinning." Two such crystals interpenetrate, more or less, but have bases parallel and the one turned on the other 30°.

BISMUTOSMALTITE.—Frenzel, *Min. Mitth.*, XVI., 523.

At the Zschorlau magnetite region there has been found a bismuth ore, partly bismuth ochre, partly bismuth and a tin-white metallic mineral occurring in minute holohedral crystals *I*, *ii* and *1*, the octahedral planes being dull and the hexahedral planes uneven. Streak black, H. 6, G. 6.92; Pb 20.17, Cu 0.69, As 61.59, Sb 0.16, Co 13.70, Fe 3.71, S 0.05. The Cu and S were due to trace of chalcopyrite. Deducting these the formula calculated is $Co(As\ Bi)_8$, that is a bismuth skuterudite.—A. J. M.

BIXBYITE, a new Mineral, and Notes on associated Topaz.—S. L. Penfield and H. W. Foote.—*Am. Jour. Sci.*, 1897, iv., IV., 105.

Brilliant, black cubes with metallic lustre, sometimes modified by {211}. H. = 6–6.5. Sp. gr. = 4.945. Crystals, evidently formed by fumarole action, occur implanted on topaz and decomposed garnet. Essentially ferrous manganite, FeO. MnO_2. Found sparingly on edge of desert thirty-five miles southwest of Simpson, Utah.—L. McI. L.

BLÖDITE, from the Punjab Salt Range.—F. R. Mallet.—*Min. Mag.*, 1897, XI., 311.

Crystals are perfect, colorless and generally transparent, with smooth or lustrous faces, and occur on rock salt. Crystallographic and optical description given and comparison made with Stassfurt crystals. Stable in the air (of London). Probably formed by solution and interaction of rock salt and the magnesium minerals in the vein.—L. McI. L.

BOURNONITE (crystallographic study) of Pontgibaud Mines, Puy-de-Dôme.—F. Gonnard.—*Bull. Soc. Min.*, 1897, XX., 312.

Early determinations criticized, therefore careful investigations made on good specimens from Praual and Roure Mines. Twenty-four forms observed, four being new.—L. McI. L.

BRUCITE (Nemalite) from Afghanistan.—F. R. Mallet.—*Min. Mag.*, 1897, XI., 211. Consists of a mass of straight, very fine, sea-green fibers. Appears to be mixed with chrysotile.

CALCISTRONTITE of Drensteinfurt, Westphalia, is mechanical not isomorphous mixture of calcite and strontianite.—*Zeit. f. Kryst.*, XXVII., 41.

CALCITE.—"Satin spar" of Alston, and determination of massive and fibrous calcites and aragonites.—L. J. Spencer.—*Min. Mag.*, 1897, XI., 184.

Determinations by Aikin, Holme, Rose and Bournon place the mineral under calcite and not aragonite. Found to be calcite, optically, by the writer. In examination of these fibrous and massive minerals, sp. gr. and microscopic characters of crushed fragments are principally relied on. Most of the onyx-marbles have been thus shown to be calcite.

L. McI. L.

CALCITE from Guanajuato.—Mugge.—*Neues Jahrb. Min.*, 1897, II., 76. Ref.

CALCIT, Hornblende, Andesin aus dem Siebengebirge.—K. Busz.—*Neues Jahrb. Min.*, 1898, I., 35.

CALCITE.—Kalkspath nach Amphibol.—E. Döll.—*Neues Jahrb. Min.*, 1897, II., 277. Ref.

CALCITE (of Couzon), additional crystallographic notes.—F. Gonnard.—*Bull. Soc. Min.*, 1897, XX., 18 and 330. Two forms, new to this locality, discovered.

CARYINITE.—Ueber die Zusammensetzung und Krystallform des Caryinite von Långban.—H. Sjögren.—*Bull. Geol. Inst. Univ. Upsala*, II., 1, No. 3; *Neues Jahrb. Min.*, 1897, I., 445. Ref. Occurs in clefts, in a mixture of schefferite, hedyphane and rhodonite, as nearly transparent nut-brown crystals with greasy lustre. Orthorhombic $a:b:c$, 0.8616:1:?. Axial plane 100. $Bx_a = b$. Optically +. $2V = 41° 50$ to $47°$. $\rho > \nu$. Composition $R_8As_2O_8$, in which R is principally Mn, Pb, Ca.

CELADONITE.—Ueber die Grünerde von Monte Baldo.—C. W. v. Gümbel.—*Ber. Ak. München.*, XXVI., 545; *Neues Jahrb. Min.*, 1897, II., 33, Ref.

CERUSSITE.—Twin crystal from Broken Hill, N. S. W.—Mugge.—*Neues Jahrb. Min*, 1897, II., 78, Ref.

CHABASIT, mit Krystallwasser, etc.—F. Rinne.—*Neues Jahrb. Min.*, 1897, II., 28.

CHALCOSTIBITE, from Huanchaca, Bolivia.—S. L. Penfield & A. Frenzel.—*Am. Jour. Sci.*, iv., 1897, IV., 31.

Highly modified prismatic crystals, averaging 2 mm. in length. Thirteen new forms observed. $a:b:c=0.5312:1:0.63955$ derived from excellent measurements of pyramids. Chemical analysis given; also crystallographic description of the mineral from other localities.

L. McI. L.

CHRYSOBERYL, von Ceylon.—M. Bauer.—*Neues Jahrb. Min.*, 1897, II., 106.

CHRYSOLITE.—Sul peridoto in paragenesi con magnetite e pirosseno, etc.—L. Fantappie.—*Rivist. Min. e. Cryst. ital.*, XVII, 3; *Neues Jahrb. Min.*, 1897, II., 445, Ref.

CINNABAR and ONOFRITE of Ouen-Shan-Tchiang.—Termier.—*Bull. Soc. Min.*, 1897, XX., 204. Cinnabar crystals have the form of those from Nikitowka (penetration rhombohedra) and exhibit interesting optical properties. Onofrite occurs in small, black, opaque patches (Hg. Zn) (S. Se).

L. McI. L.

CORUNDUM.

Corundum deposits of Georgia (preliminary report).—F. P. King.—*Bull. 2 Rept. Ga. State Geol.*

Corundum of Biella, Italy.—F. Gonnard.—*Bull. Soc. Min.*, 1897, XX., 177.

Corundum-bearing rock, from Yogo Gulch, Montana.—L. V. Pirsson.—*Am. Jour. Sci.*, iv, 1897, IV., 421. Treats of the undoubted "pyrogenetic" origin of the corundum.

On the occurrence of corundum produced by contact metamorphism in Dartmoor.—K. Busz.—*Geol. Mag.*, III., 1896, 389; abs. *Neues Jahrb. Min.*, 1897, II., 11, Ref.

Sapphires from Montana.—G. F. Kunz.—*Am. Jour. Sci.*, 1897, iv., IV., p. 417. Crystallography by J. H. Pratt, p. 424.

Found (1) in transported gravels along bars of Upper Missouri, (2) in earthy product of decomposed dikes, (3) in unaltered igneous rock. A close parallel to history of diamond-workings in South Africa. Source of gems evidently the erosion of dikes of igneous rocks.

Gems all of small size, and color not dark, hence not commercially valuable except for semi-precious or "fancy" stones. The Yogo Gulch stones more promising in color.

Yogo Gulch crystals highly etched and striated, consisting of base and rhombohedron $(30\bar{3}2)$, a new face for corundum. Prevailing type tabular parallel to base. Often show repeated growth on base of rhombohedron and base.

Emerald Bar, etc., crystals show prism, usually combined with rhombohedron $(10\bar{1}1)$ and base. Crystals rough and striated, with common tabular type (parallel to base).

L. McI. L.

The Rubies of Burma and associated minerals, their mode of occurrence, origin and metamorphoses.—C. B. Brown and J. W. Judd.—*Philosophic. Trans. R. Soc. Lond.*, 1896, CLXXXVII., 151–228; *Zeit. f. Kryst.*, 28, 224. Principally obtained from Mogok, 90 miles north, northeast of Mandalay, in gneiss with calcite, spinel, graphite, apatite, etc.

Ueber das Vorkommen der Rubine in Birma.—M. Bauer.—*Neues Jahrb. Min.*, 1896, II., 197. Crystal form, etch figures, associates, etc.

Ueber die rothen Korundkrystalle vom Dorfe Kaltaschy im Katharinenburger Ural.—A Lösch u. P Jeremejeff.—*Verh. russ. k. min. Ges.*, XXX., 476; *Neues Jahrb. Min.*, 1896, I., 392, Ref.

CLINOHEDRITE, a new mineral from Franklin, N. J.—S. L. Penfield and H. W. Foote.—*Am. Jour. Sci.*, 1898, iv., V., 289.

Small *monoclinic* crystals, of peculiar interest because belonging to the division of this system characterized by plane of symmetry but no axis of symmetry, the "domatische klasse" (Groth). Very few examples of this kind of symmetry have been observed among mineral substances $a:b:c = 0.6826:1:0.3226$. $\beta = 76° 4'$. Twenty forms identified. Cleavage perfect parallel to {010}, but not often observed. H. = 5.5. Sp. gr. = 3.33.

Composition = $(ZnOH)(CaOH)SiO_3$, in which Zn and Ca are replaced to slight extent by Mn and Mg. Often transparent with color from amethystine to nearly colorless or white. Before the blowpipe exfoliates and fuses (4) to a yellowish enamel. Reacts for Zn and is soluble in HCl with gelatinous silica.

Prevalence of forms without parallel faces gives to crystals a peculiar *inclined faced* appearance, hence its name.—L. McI. L.

CROCOITE.—Rothbleierz aus dem Umtali-District, Mashonaland.—K. A. Redlich.—*Zeit. f. Kryst.*, XXVII., 607. Occurs with talcose-schist or quartzite, often coating surface in crystals, ½–4 mm. in diameter, much distorted and cleaving easily parallel {110}. Forms observed {111} {110} {350} and a new orthodome {$\bar{4}03$}.

CUBANITE.—Die Zusammensetzung und die Constitution des Cubans.—R. Schneider.—*Jour. f. prakt. Chem.*, LII., 555; abs. *Zeit. f. Kryst.*, XXIX., 297. Specimen from collection University of Berlin gave Fe_2S_3Cu or Fe_2S_3, Cu_2S, 2FeS.

CYANITE, Mineralogical Notes.—J. H. Pratt.—*Am. Jour. Sci.*, 1898, iv., V., 126. Found on Tiel Young's farm, near North Toe River, Yancey Co., N. C. Color rich grass-green and crystals often transparent. New form {520} observed.

DANBURITE ed altre minerali in alcuni pezzi notevoli di rocce autiche etc.—L. Fantappie.—*Revist. Min. e crist. ital.*, XVI., 1–8; *Neues Jahrb. Min.*, 1897, II., 447, Ref.

DATOLITE, from Guanajuato.—O. C. Farrington.—*Am. Jour. Sci.*, 1898, iv., V., 285. Small, transparent, colorless crystals, showing unique habit and development. Seventeen forms identified. Habit (arrow-pointed) determined by predominance of orthodome {102}, by crystal being tabular with respect to this face and the clinodomes, and by fact that only the left half of the crystal is present in nature (the point of attachment being near the plane of symmetry). Crystals rarely have

rhombohedral aspect (as mentioned in Dana). Some Bergen Hill crystals somewhat similar in type. An example of "merohedrism" noted.—L. McI. L.

DERBYLITE.—E. Hussak.—*Min. Mag.*, 1897, XI., 176. A new antimono-titanate of iron ($FeO.\ Sb_2O_5 + 5FeO.\ TiO_2$) found in loose crystals (2–3 mm. long) or in fragments, of pitch black color and resinous lustre, associated with lewisite in the cinnabar-bearing sands of Tripuhy, Brazil. Orthorhombic (holohedral) system. Prism faces smooth and brilliant, macropinacoid generally rough. Twinning frequent. Hardness about 5. Sp. gr. 4.51 to 4.53. Insoluble in acid. Proved to have come from the thin bedded mica-schist of this locality.—L. McI. L.

DIAMOND.

Diamond Localities of Monastery, Orange Free State, and Griqualand (Notes on Minerals and Rocks).—A. Lacroix.—*Bull. Soc. Min.*, 1898, XXI., 21. The diamond, regarded as probably one of the elements of the harzburgite (peridotite). Garnet (pyrope), diopside, ilmenite, zircon, biotite, apophyllite, etc. L. McI. L.

Diamonds, Origin of, in South Africa.—T. G. Bonney.—Recent numbers *Geological Magazine*. Concludes that the diamantiferous rock (Kimberlite) is a volcanic breccia rather than a peculiar form of peridotite.

Recent Diamond find in Wisconsin and the probable source of these and other Wisconsin diamonds.—*Am. Geol.*, XIV., July, 1894. Most of the diamonds have been found in the Kettle moraine, and indications point to the source being in the northeastern portion of the State or still further northward.

The Diamonds from Steel.—A. Rossel.—*C. R.*, CXXIII., 113; abs. *Zeit. f. Kryst.*, XXIX., 412.

Action de l'arc electrique sur le diamant, le bore amorphe et le silicium cristallisé.—H. Moissan.—*Bull. Soc. Chim. Paris*, S. 3, XI., XII., 993, 995; *Neues Jahrb. Min.*, 1896, I., 209, Ref.

Thermal Expansion of the Diamond.—J. Joly.—*Nature*, XLIX., 480.

DICKSBERGITE, see Rutile.

ENARGITE.—L. J. Spencer.—*Min. Mag.*, 1897, XI., 196. Crystal from Peru (probably Morococha) showed new forms {031}, {132}, {394}, {131} and {392}.

FLUORITE.—F. Wallerant.—*Bull. Soc. Min.*, 1898, XXI., 44.

An investigation of the peculiar internal structure, revealed by optical anomalies and etching tests.

The author concludes that there are three varieties that can be distinguished crystallographically: (1) Holohedral cubical; (2) Ternary; (3) Monosymmetric; and that these varieties may all occur in the same crystal. The views of other investigators are also given. L. McI. L.

FUGGERIT ein neues Mineral aus dem Fassathal.—E. Weinschenk.—*Zeit. f. Kryst.*, XXVII., 577.

Light apple-green crystals, similar to gehlenite, in a white hornstone. Rather thick tetragonal plates showing base and apparent tetragonal prism. Cleavage basal perfect. Easily soluble, leaving pulverulent silica, even in dilute acetic acid, G. 3.175–3.180.

Composition equivalent to 3 akermanite and 10 gehlenite but not conforming in physical characters. A. J. M.

GALENITE.—Clivage octaédrique dans une galène de Nil St-Vincent. —G. Cesaro.—*Ann. Soc. Geol. Belg.*, Bull. 19, 76. Presence probable du tellure dans beaucoup de galènes.

GARNET.—Beiträge zur chemischen Kenntniss der Granatgruppe. *Inaug. Diss.* München.—K. H. Schnerr.—*Neues Jahrb. Min.*, 1897, I., 432, Ref. An elaborate discussion of methods of analyses with a series of analyses of the garnets of Scharn, Rothenkopf and Pregrathen. The conclusion is reached that iron manganese and titanium have no influence on the color which is referred to an unknown, but probably inorganic, pigment.

GARNET.—Rhodolite, a new variety of garnet.—W. E. Hidden and J. H. Pratt.—*Am. Jour. Sci.*, iv., 1898, V., 294.

A strikingly beautiful, gem-like garnet found as rolled pebbles in gravel beds at Mason's Branch, Macon Co., N. C. Prevailing color, a pale rosy tint inclining to purple. Composition $= 2Mg_3Al_2(SiO_4)_3 \cdot Fe_3Al_2(SiO_4)_3$, which proves it to be neither almandine nor pyrope.—L. McI. L.

Der Granat von der Turjinskschen Gruben.—E. v. Federow.—*Zeit. f. Kryst.*, XXVIII., 276.

GEDRITE.—Ueber Gedritschiefer aus den Südlichen Dalekarlien.—M. Weibull.—*Geol. För. Förh.*, XVIII., 377; *Neues Jahrb. Min.*, 1897, II., 443, Ref.

GLAUCONITE.—Zur Frage nach der Enstehung des Glaukonits.—K. Glinka.—*Ber. Soc. Nat. St. Petersburg*, 1895, No. 8; *Neues Jahrb. Min.*, 1898, I., 20, Ref. Concludes glauconite and celadonite are one species derived from decomposition of aluminous augite.

GOLD, crystalline structure of gold and platinum nuggets, etc.—A. Liversidge.—*Proc. Royal Soc. of New South Wales*; Abs. in *Am. Jour. Sci.*, iv., 1898, V., 235.

GOLD.—R. Liversidge, *Jour. Royal Soc. N. S. W.*, XXVII., 287, 299, 303, 343. Origin of moss and nugget gold. Condition of gold in quartz and calcite veins. Crystallization in hexagonal forms.

Ein tetraëdrischen ausgebildeter Goldkrystall.—K. Martin.—*Zeit. f. Kryst.*, XXIX., 278.

GRAPHITE.—Graphitkohlenstoff und gegenseitigen Beziehungen zwischen Graphit, Graphitit und Graphitoid.—E. Weinschenk.—*Zeit. f. Kryst.*, XXVIII., 291.

GREENOCKITE, amorphous, of Laurium.—A. Christomanos.—*C. R.*, CXXIII., 62, Abs.

GRUNLINGITE.—Muthman & Schroeder.—*Zeit. f. Kryst.*, XXIX., 140. The Cumberland tellurium mineral belongs to same crystalline system as tetrydymite, but, while evidently homogeneous, gives by analyses formula $Bi_4S_3Te_2$ or Bi(STe), they therefore name it Grünlingite after the curator of Munich collection.

GUEJARITE, Identity of, with Chalcostibite (Wolfsbergite).—S. L. Penfield and A. Frenzel.—*Am. Jour. Sci.*, iv., 1897, IV., 27. Also *Zeit. f. Kryst.*, XXVIII., 598. Proved by agreement in crystallographic forms and by careful chemical analyses of specimens furnished by Groth, Friedel and Cumenge.

GYPSUM, Forms of, about Paris.—A. Lacroix.—*Bull. Soc. Min.*, 1898, XXI., 39.

The modes of formation discussed: (1) By evaporation of lagoons; producing large lenticular crystals, frequently twinned, and with general absence of prismatic zone forms. (2) By decomposition of pyrite in midst of calcareous sediment; producing crystals rarely lenticular. (3) By recrystallization; producing crystals like both preceding types, sometimes remarkably clear.—L. McI. L.

GYPSUM.—Gleitflächen am Gyps.—A. Nies.—*Neues Jahrb. Min.*, 1891, I., 437, Ref. The Girgenti crystals develop gliding parallel to the pyramid (111). K. v. Kraatz describes (*Zeit. f. Kryst.*, XXVII., 604) the crystals from this locality, and (*Neues Jahrb. Min.*, 1897, II., 270, Ref.) the gypsum of Kleinschöppenstadt near Brunswick.

GÜMBELIT als Versteinerungsmittel.—K. v. Kraatz.—*Min. Mitth.*, XVII., 492. It fills the holes left by the graptolites and coal plants of various localities in Thuringia and Saxony with a white silky to pearly mass consisting of minute prisms, sometimes parallel sometimes radiating. In physical properties it agrees exactly with pyrophyllite to which the writer refers it.—A. J. M.

HALITE, metamorphic, of Salies-du Salat.—A. Lacroix.—*Bull. Soc. Min.*, 1898, XXI., 29. By dissolving the salt with water minute crystals of anhydrite, calcite, phlogopite, etc., were seen.

HALITE, pseudomorphs after, from Jamaica, W. I.—E. O. Hovey.—*Am. Jour. Sci.*, iv., 1897, III., 425.

HAMLINITE, chemical composition and occurrence with Bertrandite at Oxford Co., Maine.—S. L. Penfield.—*Amer. Journ. Sci.*, iv., 1897, IV., 313.

$[Al(OH)_2]_3[SrOH]P_2O_7$, in which Sr is partially replaced by Ba and hydroxyl by Fl. A unique composition as Sr and Ba have never before been observed as essential constituents of a phosphate.

Small crystals implanted upon feldspar and muscovite and associated with apatite, herderite and rarely bertrandite. Two prominent habits are noticed: 1st. Combination of two rhombohedra; 2d, Hexagonal prism with base, but, owing to vicinal development and rounding, appearing like steep rhombohedra. Sp. gr. 3.159–3.283.

The associated bertrandite crystals are twinned, two hemimorphic individuals being united by their basal planes.—L. McI. L.

HEMATITE.—Crystals from Dognacska, Banat.—A. Pelikan.—*Min. Mitth.*, XVI., 519. $R, -\frac{1}{2}R, \frac{4}{3}P2$ and OP.

HEULANDITE.—Notizia sopra una Heulandite baritica di Pula.—D. Lovisato.—*Atti. R. Accad. dei Lincei*, VI., 260; *Neues Jahrb. Min.*, 1898, I., 446, Ref.

ILMENITE, composition of.—S. L. Penfield and H. W. Foote.—*Am. Jour. Sci.*, iv., 1897, IV., 108.

The two theories concerning composition are: 1°. $RO.TiO_2$ ($R = Fe$ and Mg), 2°. R_2O_3 (an isomorphous mixture of Fe_2O_3 and Ti_2O_3). Definitely proved by author's analysis that, in the crystallized ilmenite from Warwick, N. Y., there is the molecule $MgO.TiO_2$. It seems reasonable to suppose that iron also is present as $FeO.TiO_2$. L. McI. L.

IOLITE.—Ueber Alpinen Cordierite-Pinit.—H. Gemböck.—*Zeit. f. Kryst.*, XXIX., 305–332.

IRON, Native in the Coal Measures of Missouri.—E. T. Allen.—*Am. Jour. Sci.*, iv., 1897, IV., 99. Occurrences of iron of terrestrial origin have until recently been subject to doubt, and even now positive occurrences are few. Specimens here described were found at such a depth as to leave no doubt of their terrestrial origin. Nickel (always in meteoric iron) is absent. L. McI. L.

IRON Meteorites, as nodular structures in Stony Meteorites.—H. L. Preston.—*Am. Jour. Sci.*, iv., 1898, V., 62.

JADEITE.—Das Vorkommen des Jadeits von "Tibet."—M. Bauer.—*Neues Jahrb. Min.*, 1897, I., 259.

KOSMOCHLORE.—H. Laspeyres.—*Zeit. f. Kryst.*, XXVII., 592. A meteoric iron, Toluca, Mexico.

$Al_6Fe_4Cr_{18}Si_{18}O_{78}$. Monoclinic emerald green mineral difficulty soluble in phosphorus salt or borax to a bluish green pearl.

KUBEIT.—L. Darapsky.—*Neues Jahrb. Min.*, 1898, I., 163.

Bright red crystals from near Loa River, Atacama, rhombic or monoclinic, ⅛ to 1½ inch long, very brittle and fragile. It is essentially an iron magnesia alum. $Fe_2O_3 2SO_3 + 2(MgOSO_3) + 18H_2O$.

LANGBANIT von der Sjögrube.—H. Sjögren: *Bull. geol. Inst. Univ. Upsala*, II., I., No. 3.—*Neues Jahrb. Min.*, 1897, I., 447, Ref.

LANGBEINITE.—O. Luedecke.—*Zeit. f. Kryst.*, XXIX., 255.

LASURIT und Ultramarinbildung.—H. Puchner.—*Zeit. f. angewandte Chemie*, 1896, 196–200; *Neues Jahrb. Min.*, 1898, I., 240, Ref.

LAURIONITE, artificial production of.—A. de Schulten.—*Bull. Soc. Min.*, 1897, XX., 186.

Colorless, orthorhombic prisms of pure laurionite were obtained by adding a hot solution of chloride of sodium to a boiling solution of neutral acetate of lead, filtering rapidly and warming the filtrate, the crystals formed after 12–16 hours. $a:b:c = 0.7366:1:0.8237$.—L. McI. L.

LAWSONITE of Corse and of New Caledonia.—A. Lacroix.—*Bull. Soc. Min.*, 1897, XX., 309. Found in glaucophane schists and saussuritized-gabbro. Usually in rectangular rods, which show the characteristic properties of lawsonite.

LAWSONIT in der Basilicata.—C. Viola.—*Zeit. f. Kryst.*, XXVIII., 553. Found in massive diabase rock in several localities on border between provinces of Basilicata and Calabria in altered plagioclase and also with quartz and albite. The crystals are idiomorphic, but microscopically small, they are colorless, and transparent in thin sections.

LEONITE.—Ueber die Krystallform des Leonit aus den Steinsalzlagern von Leopoldshall.—C. Tenne.—*Zeit. d. d. Geol. Ges.*, 1896, 632–637; *Neues Jahrb. Min.*, 1898, I., 260, Ref.

Monoclinic $a:b:c = 1.03815:1:1.23349$, $\beta = 95°10'$ $MgSO_4$, $K_2SO_4 . 4H_2O$, that is a pure potassium bloedite occurring on halite in kainit deposit as thick tabular crystals with few faces, also smaller, 2 mm. by ½ mm., brighter and better formed. Color reddish or grayish.

LEUCIT und Analcim und ihre gegenseitigen Beziehungen.—C. Klein. —*Neues Jahrb. Min.*, Beil. Bd., XI., 475.

An investigation of optical characters at different temperatures, using No. VI. Fuess and modified universal rotation apparatus (Figure given), with water jacketed objective and temperatures determined by d'Arsonval galvanometer. The simultaneously rotating nicols of the microscope make it unnecessary to solidly unite the stage to the microscope; it is, therefore, possible to use auxiliary stage with heating chest employing gas and oxygen, the latter only for temperatures above 600° C.

Experiments confirm his previous conclusion that leucite is isotropic at high temperatures, but anisotropic and biaxial with a small axial angle at lower temperatures. Concludes the system to be orthorhombic and not anomalous tetragonal. Points out that twinning parallel 110 is always observed and that frequently the crystal is built of lamellæ which he does not believe to be of secondary origin.

Analcite, which Mallard considered to be pseudo-isometric composed of rhombic pyramids with common apex at the center, Klein considers to be isometric but anomalous in spots due partly to the loss of water, partly to the temperature.—A. J. M.

LINARITE in crystals with quartz and anglesite at San Giovanni, Sardinia.—L. Bragnatelli.—*Rend. Inst. Lombard*, XXV., 3–10; *Zeit. f. Kryst.*, XXVIII., 307.

MAGNESITE formed by action of carbonated water and humus from organic substances upon the lherzolite of Casellette.—G. Piolti.—*Mem. Ac. Sci. Torino*, Mch., *Neues Jahrb. Min.*, 1897, II., 442 Ref.

MARCASITE of Pontpéau (Ille-et-Vilaine) and its Pseudomorphs.—A. Lacroix.—*Bull. Soc. Min.*, 1897, XX., 223.

Found as free crystals and crusts, the former being much elongated parallel to *c* and nearly always polysynthetic. Sometimes twinned parallel to prism. Replacements of pyrrhotite by marcasite (at times with pyrite and galenite also) very interesting, the flattened marcasite crystals grouped with their *b* axis parallel to the *c* axis of the pyrrhotite Marcasite of this locality alters easily.—L. McI. L.

METABRUSHITE.—Sur le minéral cristallisé formé dans un cercueil de plomb aux dépens d'un cadavre.—*C. R.*, CXXJV., 419. The brain of human body, buried 1630, was converted into a geode with brilliant 8 mm. crystals apparently metabrushite. Gonnard described similar crystals with a skeleton from Solutre.

METEORITES, four new Australian.—H. A. Ward.—*Am. Jour. Sci.*, IV., 1898, Vol. V., 135.

MICAS of Three Rock, Mountain Co., Dublin.—J. P. O'Reilly—*Min. Mag.*, 1897, XI., 199.

Determined by Haughton to be margarodites and lepidomelanes, by later analyses (M. W. Robertson, 1889) more probably biotites. Contain specks or flakes of bronze or black mica. Analyses show presence of small per cent. of Cu_2O.

MONAZITE from Idaho.—W. Lindgren.—*Am. Jour. Sci.*, IV., 1897, Vol. IV., 63. Occurs quite plentifully in the gold washings, associated

with ilmenite and zircon. Probably not of commercial value, the sand of the gravels and lake beds of the Idaho basin is derived from granite and associated dike rocks.—L. McI. L.

Monazite and Xenotime, in European rocks.—O. A. Derby.—*Min. Mag.*, 1897, XI., 304.

MOLYBDENITE, the Crystallization of.—A. P. Brown.—*Proc. Acad. Nat. Sci. Phil.*, 1896, I., 210.

PHENACITE. Ueber krystallisirten Phenakit aus Schlesien.—C. Hintze. —*Zeit. f. Kryst.*, 1898, XXVIII., 174.

PLAGIONITE, crystallography of.—L. J. Spencer.—*Min. Mag.*, 1897, XI., 192. The doubtful forms {776}, {$\bar{7}$.7.16} and {0.10.3} of Luedecke not confirmed. Fifteen new forms determined. Measurements often complicated by striæ. Sp. gr. about 5.5.

PLANOFERITE.—L. Darapsky.—*Zeit. f. Kryst.*, XXIX., 213. Deep brown crystals of $Fe_2O_3 . SO_3 . 15H_2O$; a sulphate near raimondite, on olive green copiapite.

PLUMBOFERRITE von der Sjögrube in Kirchspiel, Grythyttan, Örebro.—L. J. Igelström.—*G. För. Förh.*, 1894, XVI., 594; *Neues Jahrb. Min.*, 1896, I., 15, Ref.

POLYLITE of Thomson.—A. Lacroix.—*Bull. Soc. Min.*, 1897, XX., 308. Described by Thomson as a black mineral, with vitreous lustre and one cleavage, resembling amphibole, and found with magnetite near Hoboken, N. J. Considered by author to be undoubtedly an artificial product from some old iron metallurgical works. Hence name should be given up.—L. McI. L.

PREHNITE.—N. J. Harrison, Jr.—*Min. Mag.*, 1897, XI., 198. Crystals found at the "Gimlet," Pwllheli, Wales.

Pyroëlektrischen Eigenschaften und die Krystallform des Prehnit.—H. Traube.—*Neues Jahrb. Min.*, Beil Bd., IX., 134. Crystals from Jordansmühl, Silesia, were + on one face of 100, — on the other, that is show polarity on *a* and cannot be centro-symmetric.

PSEUDOGAYLUSSITE of Holland.—F. J. P. van Calker.—*Zeit. f. Kryst.*, XXVIII., 556. Concludes that there is not sufficient ground upon which to decide the original mineral.

PYRARGYRITE.—Mugge.—*Neues Jahrb. Min.*, 1897, II., 79, Ref. Twin striations described.

PYRITE.—Comparative study of the chemical behavior of pyrite and marcasite.—*Proc. Am. Philos. Soc.*, Phila., XXXIII., 225.

Decomposition products of Pyrite of the Paris basin, etc.—A. Lacroix. —*Bull. Soc. Min.*, 1897, XX., 288. Melanterite, gypsum, websterite, halotrichite, siderite, etc.

PYROXENE —Beitrage zur Kenntniss der Pyroxenfamillie.—E. A. Wülfing.—*Min. Mitth.*, XV., 29.

Breislakit.—A. Wichmann.—*Zeit. f. Kryst.*, XXVIII., 529.

QUARTZ, Note upon growth of.—F. Wallerant.—*Bull. Soc. Min.*, 1897, XX., 173. The crystals described *appear* to be formed by the building up of a series of hollow hexagonal prisms.

On "quartzine" and on the origin of rotary polarization of quartz.—Fred. Wallerant.—*Bull. Soc. Min.*, 1897, XX., 52.

Die Hyacinthin der Gypse des Röth bei Jena. E. Zschimmer.—*Min. Mitth.*, XV., 457.

QUIROGITE.—F. Navarro, Spanish minerals in the Madrid Nat. Hist. Museum.—*Annal de la Soc. Esp. de Hist. Nat.*, Vol. XXIV., 1896.

Lead gray color on exposed portions, resembles galenite. Tetragonal $a:c = 1:1.286$, showing forms (111) (100) (001) (112?) (706?). H = 3. Sp. gr. = 7.22. 2 PbS. $3Sb_2S_3$. Found at mines of San Andres, Georgina, Paraiso, etc., Prov. Palmeira.—L. McI L.

RASPITE.—C. Hlawatsch.—*Ann. Mus., Wien.* XII., 1898, *Zeit. f. Kryst.*, XXIX., 130.

Monoclinic crystals of $PbWO_4$ always poor in faces, twinned parallel to 100 and tabular to 100. There are two occurrences: in one the raspite is wax brown and associated with clear yellow tabular crystals of stolzite on a pulverulent galena; in the other the raspite is yellow to brown and associated with reddish pyramidal crystals of stolzite on limonite. Lustre adamantine, index of refraction 2.6 approx. H. 2.5. Occurs at Broken Hill Mines, N. S. W.

REALGAR.—Ueber eine neue Form {450} aus Realgar von Allchar, Macedonien.—V. Hackmann.—*Zeit. f. Kryst.*, XXVII., 608.

RHODOPHOSPHIT und Tetragophosphit Zwei neue Mineralien von Horrsjöberg in Wermland.—L. J. Igelström.—*Zeit. f. Kryst.*, XXV., 433.

RHODOLITE, see garnet.

RŒBLINGITE, new silicate containing sulphur dioxide and lead.—S. L. Penfield and H. W. Foote.—*Am Jour. Sci.*, iv., 1897, III., 413.

Occurs in dense, white, compact masses of minute prismatic crystals at the Parker shaft, Franklin Furnace, N. J. These, optically examined, showed parallel extinction and weak double refraction, but were too small for determination of system. Sp. gr. 3.433; hardness a little under 3; composition possibly $= 5\,H_2CaSiO_4 + 2CaPbSO_4$. The mineral is of special interest, being the first sulphite observed in nature.

RUTILE.—Beiträge zur Kentniss des Rutils, Cassiterits und Zirkons.—H. Traube.—*Neues Jahrb. Min.*, 1895–6, Beil. Bd. X., 470. By etching tests all are holohedral.

RUTILE.—Weibull and Upmark show Dicksbergite of Wermland, Sweden, to be rutile.—*Geol. För. Förh.*, 1896, XVIII., 231, 523.

Mugge describes, *Neues Jahrb. Min.*, 1897, II., 82, Ref., a rutile with parting parallel (902).

SARTORITE.—Den Skleroklas von Binn.—H. Baumhauer.—*Ber. Ak. Berlin*, XII., 243; Abs., *Zeit. f. Kryst.*, XXIX., 159.

Four crystals, 1–2 mm. long, show 59 forms (22 previously known). By analysis of one of the crystals obtains the formula 3 ($PbS.As_2S_3$) + 2 $PbS.As_2S_3$.

SEPIOLITE.—Meerschaum von Eskishehir in Kleinasien.—E. Weinschenk.—*Zeit. f. Kryst.*, XXVII., 574. Formula $H_4Mg_2Si_3O_{10}$, as with fibrous variety from Utah.

SERPENTINE.—Ueber Umwandlung von Chondrodit, Tremolit und Dolomit in Serpentin von der Kogrube Nordmarken.—H. Sjögren.—*G. För. Förh.*, XVII., 267; *Neues Jahrb. Min.*, 1897, I., 19 Ref.

SODA NITER.—Zur Morphologie des Natronsalpeters.—L. Wulff.—*Ber. Ak. Berlin*, XXXII., 715, XXXVIII., 135, 879.

Beitrag zur Kenntniss des Sperryliths.—T. L. Walker.—*Zeit. f. Kryst*, XXV., 561.

STANNITE.—Die Silber-Zinnerzlagerstätten Bolivias.—A. W. Stelzner.—*Zeit. d. D. Geol. Gesell.*, XLIX., 1897. Describes crystallized stannite, the crystals black and adamantine, of about 5 mm. diameter and showing combinations of both tetrahedra, often equally developed but differing in luster. I, $i-i$, $\frac{m-m}{2}$ also occur.

STEENSTRUPINE. Zur Kenntniss des Steenstrupins.—J. C. Moberg.—*Zeit. f. Kryst.*, XXIX., 386.

By examination of later and better specimens of the mineral from Kungerdluarsuk, described by Lorenzen, the mineral is placed crystallographically nearer to eudialyte than to melanocerite with $c = 1.0711$. The characters are redetermined. No simple formula is found, the principal constituents being SiO_2, $(CeLaDi)_2O_3$, Na_2O, H_2O.

STEPHANITE.—L. J. Spencer.—*Min. Mag.*, 1897, XI., 196. A bright crystal from Chili showed the new forms {551} and {10.10.13} as narrow faces in zone [001,110].

STILBITE, Physikalisch-chemische Untersuchungen am Desmin.—F. Rinne.—*Neues Jahrb. Min.*, 1897, I., 41-60.

SULPHOBORITE.—Die chemische Zusammensetzung und das Specifisches Gewicht Sulfoborits.—K. Thaddeéf.—*Zeit. f. Kryst.*, XXVIII., 264.

Specific gravity obtained in benzol and methylene iodide (method described in detail) with Pycknometer; repeated determinations gave as a final average 2.416 at 4°C. Results of analyses led to formula $4MgHBO_3$, $2MgSO_4$, $7H_2O$.

SYLVITE.—Untersuchung eines Sylvins von Stassfurt.—W. Schimpf.—*Zeit. f. Kryst.*, 1897, XXV., 92.

TALC.—Genesis of the deposits of St. Lawrence Co., N. Y.—C. H. Smyth, Jr.—*S. of M. Quart.*, XVII., 333.

Deposits of talc of complex origin. Three stages noted; 1° Formation of an impure siliceous and magnesium limestone; 2°. Metamorphism of this rock and conversion into enstatite and tremolite schist; 3°. This schist, by action of water charged with CO_2, converted into talc.

L. McI. L.

TETRADYMITE.—Muthman & Schroeder.—*Zeit. f. Kryst.*, XXIX., 140.

The Orawicza and Schubkau specimens are Bi_2Te_2S. See under Grünlingite.

THURINGITE.—Ueber die Beziehungen des Thuringit zum Chlorit und über die chemische Constitution der Chloritgruppe.—K. Dalmer.—*Neues Jahrb. Min.*, 1898, I., 165. Discussion of analyses and forms.

TITANITE.—Die pyroëlektrischen Eigenschaften des Titanits und des Strontiumbitartrats.—H. Traube.—*Neues Jahrb. Min.*, 1896-7, Beil Bd., XI., 209.

Die Titanitkrystalle in Brennergneiss.—A. Rodewyx.—*Min. Mitth.*, XVII., 544. The characteristic constituent of the Brenner gneiss is titanite in small, fragile, yellow-brown crystals. Twins not observed;

forms usually $\bar{1}23$ and 001, or $\bar{1}01$, rarely 011 and $\bar{1}13$. Pleochroism weak. Often coated with crystals of green sphene.

TOPAZ crystals from Perak.—A. Lacroix.—*C. R.*, CXXIII., 135. Abs. *Zeit. f. Kryst.*, XXIX., 413.

Notes on the Topaz from Mino.—Tadasu Hiki.—*Jour. Coll. Sci. Univ. Tokyo*, IX., I., 8; *Neues Jahrb. Min.*, 1897, I., 438, Ref.

TOPAZ.—Sur les inclusions dans les topazes de l'Oural et de la Saxe.—M. Tolstopialow.—*Vh. Min. Ges.* (2), XXXIII., 289–306; *Neues Jahrb. Min.*, 1898, I., 446, Ref.

The litt e included tourmalines in topaz crystals of Ilmen Mts. are commonly perpendicular to faces {110} {120} {011} {111} {112} and {113} and lie principally in a zone 2 mm. wide, the central portion of a basal section rarely showing any of the included crystals.

It appears that a disturbance in crystallization begins as soon as inclusion zone forms, that the crystal molecules of topaz unite to little spheres which are deposited in great numbers on the inner edge of the zone. The enclosed tourmalines are from .01 mm. to several millimeters in length and are pyramidal and not prismatic. The color by transmitted light is brown or green, in incident light black.—A. J. M.

TOURMALINE, Secondary Enlargement of.—O. A. Derby.—*Am. Jour. Sci.*, 1898, iv., V., 190. Evidently clastic grains of tourmaline enlarged as in the well-known case of enlarged quartz grains.

TRIPUHYITE, a New Antimoniate of Iron.—E. Hussak and G. T. Prior.—*Min. Mag*, XI., 1897, 302.

Occurs in the cinnabar-bearing gravel of Tripuhy, Minas Geraes, Brazil, associated with the new minerals lewisite and derbylite. Probably derived from the muscovite-schists. Found only in micro-crystalline aggregates of a dull greenish-yellow color; biaxial with high index of refraction and strong double refraction. Composition $= 2FeO.Sb_2O_5$. Sp. gr. = 5.82 at 19° C.—L. McI. L.

VESUVIANITE. Der Vesuvian von Friedeberg in Schlesien—H. V. Graber.—*Min. Mitth.*, XVII., 384. Describes two crystals belonging to Prague University.

Ueber die Chemische Zusammensetzung und Constitution des Vesuvians und des Waluits.—P. Jannasch und P. Weingarten.—*Zeit. f. Anorg. Chemie*, XI., 40; *Neues Jahrb. Min.*, II., 1897, 259 Ref.

$(Al,Fe,Ti)(Ca,Mg,Fe,Mn)_2(H,K,Na,Li)$ based on analyses by improved methods.

WELLSITE, a new mineral.—J. H. Pratt and H. W. Foote.—*Am. Jour. Sci.*, iv., 1897, III., 443.

Small, colorless or white isolated crystals with vitreous lustre, intimately associated with transparent chabazite. Monoclinic and twinned similarly to phillipsite, to which it is closely related in composition.

$$(Ba, Ca, K_2)O \cdot Al_2O_3.3SiO_2 + 3H_2O.$$

Sp. gr. = 2.278 — 2.366. H = 4 to 4.5. Occurs at Buck Creek Corundum Mine, Clay County, N. C.—L. McI. L.

WITHERITE von der Grube Himmelfürst bei Freiberg.—A. Weisbach.—*Neues Jahrb. Min.*, 1898, I., 252.

Pseudohexagonal pyramids about 2 cm.

WOLFSBERGITE, see Guejarite and Zinckenite.

WOLFRAMITE.—Frenzel.—*Min. Mitth.*, XVI., 523. Crystals of marked monoclinic shape from several Bolivian localities.

XANTHOPHYLLITE.—Eine neue Aufstellung der Krystalle des Waluewit.—G. Fels.—*Zeit. f. Kryst.*, XXIX., 279.

Calculates anew the geometrical constants, bringing them very near those of biotite of Vesuvius.

Xanthophyllite $a:b:c = 0.5774:1:0.5763$. $\beta = 109° 35½'$
Biotite $a:b:c = 0.5777:1:1.15827$. $\beta = 109° 25'$.

XENOTIME, Remarkable occurrence of.—G. C. Hoffmann.—*Am. Jour. Sci.*, iv., 1898, V., 235.

A mass (312 grams) made up of a closely compacted aggregation of slender prisms, dark reddish-brown in color with resinous lustre; found in a coarse granite vein at Calvin, Ontario.

ZEOLITES, water of.—G. Friedel.—*Bull. Soc. Min.*, XXI., 5, 1898.

Water is present under very different conditions from those affecting hydrated salts.

(1) Water can be eliminated without destroying the crystalline structure. (2) Water, once eliminated, can be replaced by any gas or liquid. (3) The manner of dissociation of the zeolites is very different from that of the hydrated salts.

The results of the author's tests on analcite give a novel argument in support of the theory that the water of zeolites is simply included and not chemically combined.—L. McI. L.

Neuer Zeolithvorkommnisse in der Tyroler Centralalpen.—P. C. Habert.—*Zeit. f. Kryst.*, XXVIII., 239–263.

Zeolite Locality of Cape Djinet, Algeria.—L. Gentile.—*Bull. Soc. Min.*, XX., 210, 1897.

The Zeolithic minerals of Table Mountain.—W. Cross.—Monograph XXVII., *U. S. Geol. Surv.*, 292–296; abs. *Neues Jahrb. Min.*, 1898, I., 457.

ZINCKENITE and Wolfsbergite (Chalcostibite) from Wolfsberg in Harz.—L. J. Spencer.—*Min. Mag.*, 1897, XI., 188.

Considered as isomorphous. Zinckenite crystals are rarely simple, while wolfsbergite crystals are commonly so. Zinckenite crystals described, had been labelled wolfsbergite on account of habit, but proved to be probably the former by chemical analysis and absence of distinct cleavage. The small indistinct, blade-shaped crystals, forming a cellular aggregate, appeared with deep striations parallel to length and usual absence of terminal plates. New face $c\{001\}$ recorded. Wolfsbergite twin described as composed of two tabular individuals, with trace of plane of junction parallel to striations on basal plane.—L. McI. L.

ZIRKELITE, Chemical composition of.—G. T. Prior.—*Min. Mag.*, 1897, XI., 180.

Weight of material used for analysis = 0.4716 grm. Molecular ratios correspond approximately to formula RO. $2(Zr, Ti, Th)O_2$. Sp. gr. redetermined and found to be 4.741.

Zirkelite ein Prioritätsfrage.—M. E. Wadsworth.—*Neues. Jahrb. Min.*, 1898, I., 164. Objects to the use of the name zirkelite because of previous use as a rock name.

ZIRCON.—J. H. Pratt.—*Am. Jour. Sci.*, IV., 1898, Vol. V., 127.

Found at New Stirling, Iredell Co., N. C., in well developed crystals (unit pyramid chief form), reddish-brown in color and from 1 cm. to 2.5 cm. in diameter.—L. McI. L.

Zircon, Anatas, und Gyps aus Porphyrton von Halle.—K. v. Kraatz.—*Neues Jahrb. Min.*, 1897, II., 213. Little crystals obtained in the sifting of porcelain clay.

UNNAMED SPECIES.—An apparently new Silicate.—G. Cesaro.—*Bull. Ac. Belg.*, 1895, XXIX., 508. Abs. *Ziet. f. Kryst.*, XXVIII., 107.

A pale rose red or colorless mineral accompanying the Hexagonite of Edwards, N. Y. H. 4½, Orthorhombic, cleaves parallel to two pinacoids. Acute bisectrix normal to the better cleavage. $\beta - \gamma = 0.004$, (—) $2E = 83°30'$. Easily fusible, insoluble anhydrous silicate MgMnCa.

LOCALITY REPORTS.

Beiträge zur mineralogie Bayerns.—E. Weinschenk.—*Zeit. f. Kryst.*, XXVIII., 135.

Ueber einige neue mineralvorkommen des bayerischen Waldes.—E. Weinschenk.—*Zeit. f. Kryst.*, XXV., 357

Die Minerallagerstätten des Gross-Venedigerstockes, etc.—E. Weinschenk.—*Zeit. f. Kryst*, XXVI., 337–508.

Minerallagerstätten der Serpentine in den östlichen Centralalpen.—E. Weinschenk.—*Zeit. f. Kryst.*, XXVII., 559.

Einiges minerale der umgegend von Schlaining.—A. Schmidt.—*Zeit. f. Kryst.*, XXIX., 193.

Natur und Verbreitung der Zeolithe in den Schiefern der Alpen.—P. C. Habert.—*Zeit. des Ferdinandeums Innsbruck*, III., 5–57; *Neues Jahrb. Min.*, 1898, I., 247, Ref.

Das mineral vorkommen Friedeberg (Schlesien).—F. Kretschner.—*Min. Mitth.*, XV., 9.

Die Minerale des Harzes, O. Luedecke, Berlin, 1896, *Zeit. f. Kryst.*, XXIX., 176.

Beiträge zur Mineralogie Böhmens, III.—F. Katzer.—*Min. Mitth.*, XVI., 504.

Mineralogische Mittheilungen über den Stromboli.—A. Bergeat.—*Neues Jahrb. Min.*, 1897, II., 109.

Rocks and minerals of the diamond mines of Kimberley.—T. G. Bonney, Miss C. A. Raisin.—*Geol. Mag.*, London, 1895, II., 496.

The minerals occurring in the Australian Broken Hill Consols Mine.—Geo. Smith.—*Jour. Roy. Soc. N. S. Wales*, XXVII., 368–375.

Also E. F. Pitman, *Ibid.*, 366–368; A. Liversidge, *Ibid.*, XXVIII., 94–98; D. A. Porter, XXVIII., 39–44; E. F. Pitman, XXIX., 48, *Neues Jahrb. Min.*, 1896, I., 397, Ref.

Brief Notes on Minerals of the Castle Mountain District.—W. H. Weed and L. V. Pirsson.—*Bull. U. S. Geol. Surv.*, No. 139.

A contribution to mineralogy of Wisconsin.—W. H. Hobbs.—*Bull. Univ. Wis.* Science, Series I., 109, 1895.

SUNDRIES.

Fluorides, silicates and oxides which form at low temperatures.—H. J. Johnston Lavis.—*Geol. Mag.*, London, 1895, II., 309.

Crystals of hornblende and mica coating a fossil bone which when heated became black and gave odor of burned horn. The conclusion is these (and other species) were formed at a temperature too low to decolorize the bone. Probably by action fluorine.

The genetic relations of certain minerals of Northern New York.—C. H. Smyth, Jr.—*Trans. N. Y. Acad. Sci.*, XV., 260.

Pyroxene, phlogopite, scapolite, titanite and feldspar, together with apatite, tourmaline, wollastonite, quartz and zircon, often occur together and in several instances are clearly a product of contact metamorphism. Heated solutions and gases the immediate agents of mineral formation.

Pseudomorphs from Northern New York.—C. H. Smyth, Jr.—*Am. Jour. Sci.*, IV., 1897, Vol. IV., 309.

Pyroxene after Wollastonite. Mica after Scapolite and Pyroxene.

As a general rule in this region the addition of magnesia (from surrounding limestone) is very common in the formation of pseudomorphs.

Pseudomorphs (British).—H. A. Miers.—*Min. Mag.*, 1897, XI., 263.

Embracing: (1) Pseudomorphs, hitherto undescribed; (2) those for which the evidence is insufficient; and (3) list of those which may be regarded as established.—L. McI. L.

BOOK REVIEWS.

A Laboratory Guide in Qualitative Chemical Analysis. By H. L. WELLS, M.A., Professor of Analytical Chemistry in the Sheffield Scientific School of Yale University. First edition, New York, John Wiley & Sons; London, Chapman & Hall, ltd. 1898. 8vo., 154 pp.

In books of instruction like the one before us, the individuality of the teacher, and the method which he finds *for himself* the most efficient in imparting the desired information, is the most noticeable feature. In the hands of some other teachers the method and the book might prove more or less ineffective.

To one accustomed to the usual plans of instruction this book would seem rather "topsy turvy" in its presentation of the subject.

The arrangement is:

Part I. Analytical Course.
Part II. Theory.
Part III. Descriptive Part.

In Part I the student is instructed to make up a number of solutions each containing one of the bases usually sought in qualitative work, as solution of alum, of antimony chloride, etc. The list is arranged alphabetically, and thus gives no clue to the analytical classification. Then the student is called upon to find out which of these solutions give a white with HCl, then with H_2S, etc., and the usual methods of

separation are given, rather by suggestion than otherwise. This plan is no doubt calculated to teach the analytical classification and the reasons for it. The acids are treated in a somewhat similar manner to the bases. A chapter at the *end* of this part gives directions for making up the reagents used.

The Theoretical part (II) is in accord with its title, dealing with radicals and formulæ, ionization, precipitation, crystallization and equations.

The chapter on ionization and ions, is of value, as serving to give the student some ideas on that topic, which so far as we know has never before been introduced in a book of this character. The chapter on equations would seem to be rather more confusing than helpful to a student.

The Descriptive part (III) gives the special reactions of the different elements and radicals when in solution, the reactions used in qualitative and quantitative separations being more particularly given. The order of description is also in this case alphabetical.

On the whole, the book presents some original features many of which are suggestive and may prove useful to students and teachers. E. W.

A Short Course in Inorganic Qualitative Analysis for Engineering Students. By J. S. C. WELLS, Ph.D., Instructor in Analytical Chemistry Columbia University. First edition, New York, John Wiley & Sons; London, Chapman & Hall, ltd. 1898. 8vo., 294 pp.

As intimated in the preface, this book is intended to give essentially the information in Fresenius' Manual of Qualitative Analysis, in a more condensed and assimilable form. The plan is therefore to all intents that of Fresenius, with the insertion of certain matter which the author has found to be helpful. The arrangement of the subject suggests the question which often vexes instructors in analytical chemistry. Given the analytical classification of the bases, at which end should a student begin? Beginning with the alkalies has the advantage of presenting first the study of the most positively basic of the bases. On the other hand the precipitation tests for these are the most difficult to obtain by an inexperienced student, and moreover in a systematic process of qualitative or quantitative analysis, the hydrochloric acid group (at the other end of the series) comes first, while the separation and detection of the alkalies, are the last.

Another point suggested in this connection is whether the lines between general chemistry and qualitative analysis should be so sharply drawn as is often the case, especially when the qualitative laboratory is the first in which the student has any work in laboratory manipulations. Where the object is economy of the student's time—a short course—we have seen most excellent results where general chemistry including hints of the reactions employed in manufacturing chemistry, have been merged in with qualitative analysis.

As a book of instruction this one seems to be more suited to the particular scheme of instruction of which the author's work is a part, than to be adapted for general use. E. W.

Electrolysis and Electrosynthesis of Organic Compounds. By DR. WALTHER LÖB, translated by H. W. T. LORENZ, A.M., Ph.D. New York, Wiley & Sons. 1898. 12mo., 103 pp.

The book is a translation from the second German edition, which has just been revised by Dr. Löb. It is divided into two sections, one treating aliphatic and the other aromatic compounds. As the knowledge of the electrolytic behavior of organic compounds is but limited at the present time the author aims only at giving a clear résumé of what has already been done and refers the reader to the original journal articles for more complete information. Books of this type are most valuable, as they give not only much interesting information, but also enable the reader to follow out any particular line by grouping together for his use the references bearing on the subject. The various organic compounds are taken up in accordance with the usual classification and their products of decomposition described. Among the most interesting syntheses are iodoform and some of the aniline and napthalene dyes which are now made electrolytically on a commercial scale. E. H. M.

The Barometrical Determination of Heights—A Practical Method of Barometrical Levelling and Hypsometry for Surveyors and Mountain Climbers. By F. J. B. CORDEIRO, Surgeon United States Navy. Spon and Chamberlain, 12 Cortlandt St., New York. 1898. Leather, 4¾ × 6¾ ins.; 28 pages. Published price, $1.00.

The pages of this pocket book are devoted to the establishment of a formula similar to those of LaPlace, Guyot, Baily, Williamson and others, giving somewhat different constants and forms to the correction factors. A description of the practical handling of a mercurical barometer outfit during hypsometric observations is made secondary and not given in detail.

The barometric coefficient is not considered constant as in many other formulas, but is computed for each observation from the observed pressure, temperature and relative humidity. Especial attention is given to the uncertainty of the effects of differences of latitude and altitude upon the correction factors resulting through the variations of gravity. The question of a humidity correction is discussed at length and established by the use of Regnault's figures for the physical constants entering the formula. No space is allotted to barometric oscillations with changes in time or to pressure gradients with differences of wind and weather. Therefore the formula assumes and the book advises the determination of a height in stages of 500 feet or less so that the barometers can be read under similar conditions of the atmosphere. For ordinary practical operations at least this is a proper treatment of the problem.

The book gives a table expressing the elastic force of saturated aqueous vapor for each degree of the Fahrenheit scale from—31° to 100° and an example worked at some length showing the application of the formula. An appendix on a proposed form of an air barometer with its theoretical advantages concludes the essay.

The book, so far as it treats the subject, should prove interesting to the student of hypsometry. And for practical use the formula and method will be found to lend themselves readily to computation and accuracy respectively. C. D., JR.

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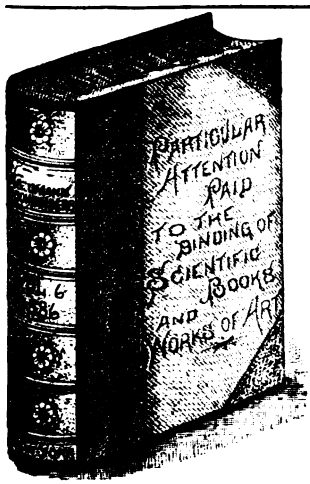

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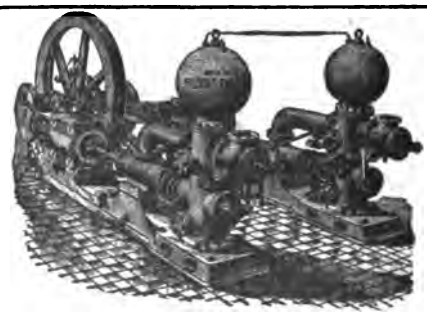

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VOL. XX. APRIL, 1899. No. 3.

SOME CONTACT PHENOMENA OF THE PALISADE DIABASE.

BY JOHN DUER IRVING, M.A.,

Fellow in Geology Columbia University.

Although the contact phenomena produced by the intrusion of diabase on sandstones and shales have been extensively studied in many localities, it is somewhat surprising that the attention of geologists has not been more attracted to the most famous of our Triassic diabases—the Hudson River Palisades. With the exception of a few observations in papers only incidentally concerned with the subject, the writer has been able to find nothing in the literature published prior to 1892. In the spring of this year, however, there appeared a short paper by Andreae and Osann, entitled: "The Plutonic Contacts on the Intrusive Diabase of New Jersey."* This paper is an excellent and comprehensive work on the contacts of the diabase, but it is to be observed that the time which the authors were able to devote to field work was somewhat limited, and that the opening of the new railroad tunnel of the New York, Susquehanna and Western Railroad has revealed exposures not then accessible. It has, therefore, been possible tb obtain some additional and interesting data, which are in the main in accordance with the conclusions of the authors just mentioned.

The effects of the intrusion may be conveniently divided into two

* A. Andreae and A. Osann, Tiefencontacte an den intrusiven Diabasen von New Jersey, Verh. des Naturhist. Med. Ver. zu Heidelberg, N. F., V. 1.

groups: *the internal* or effects on the intrusion itself, and *the external* or effects on the sediments through which it was intruded.

Internal Effects.—The most noticeable of these is the increasing fineness in grain as we proceed from the center of the sheet toward the contacts. This has been noted by Darton* and many otherd in works on the geology of the Palisades. Andreae and Osann † call attention to it and show that as we approach the contacts the customary ophitic texture of the diabase passes into one distinctly porphyritic while the hypersthene, which is one of the characteristic minerals here, disappears and is replaced by olivine. They further note that biotite becomes much richer at the contacts than in the main body of the diabase. In reading over this literature it occurred to the writer that a series of determinations of the density of the rock at different distances from the boundaries of the sheet would be of interest. Such determinations have been made by Professor Harker on some intrusions in Great Britain, showing that the increase in density varies directly as the bases, the rock becoming more and more basic near the edges of the intrusion.

A section was accordingly made across the Palisades on the line of the railroad tunnel above mentioned, and a series of specimens collected from points at various distances from the east and west borders. It must be borne in mind that the Palisades form a sheet that has been injected between sediments which dip toward the west at an angle sometimes as high as 17°, so that elevations taken at points on the surface of the sheet as it now exists do not represent the true distances on a line normal to the two contacts. To obviate this difficulty a section was plotted from the topographical map published by the U. S. Survey and points located from which specimens were obtained. From these the writer was then able to determine the relative distances from either contact. (See diagram.)

The respective densities of the specimens were determined with the following results:

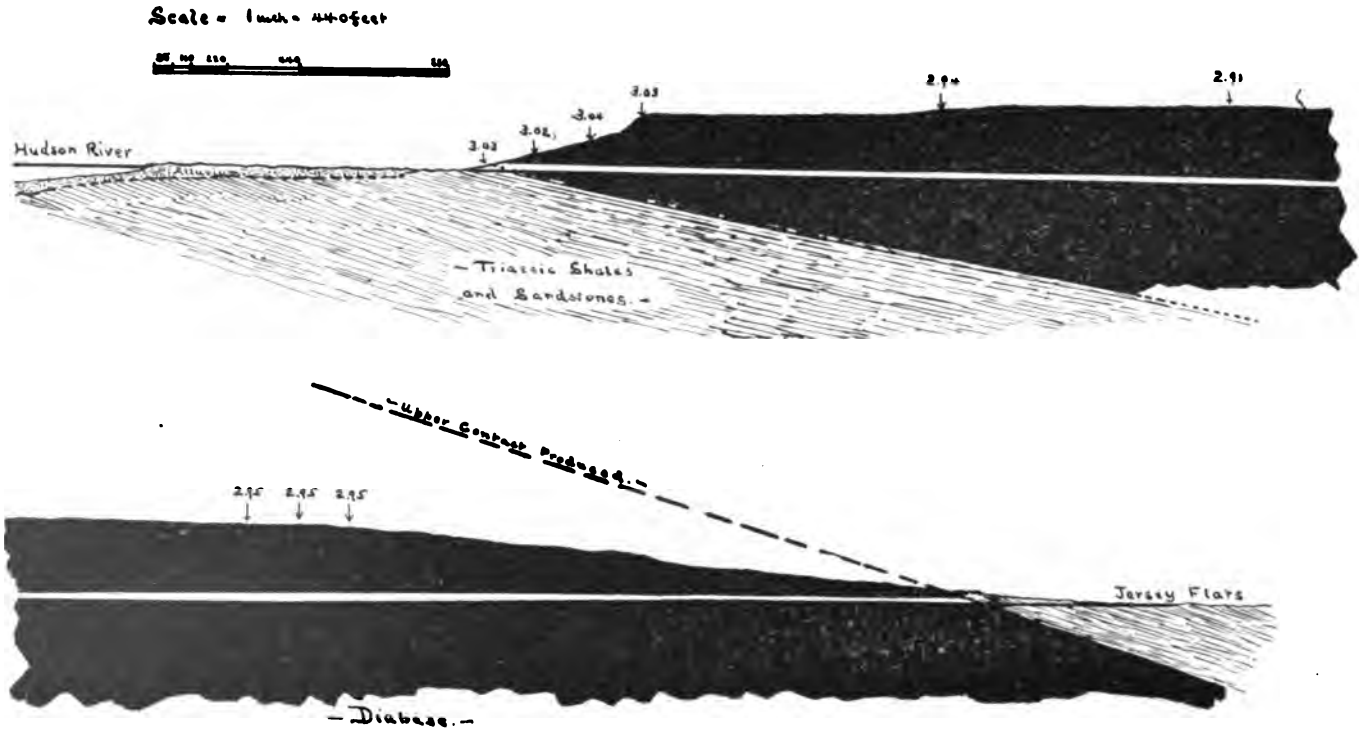
At a series of points, short distances apart and near the lower contact the rocks showed a very uniform density of about 3.03. At a distance that may be seen to be about one-third of the way between the upper and lower contacts this fell to 2.94. At a point about one-half the distance across the existing exposure

* Bulletin No. 67, United States Geological Survey, p. 72.

† Op. cit.

SECTION ACROSS PALISADES ALONG LINE OF NEW YORK, SUSQUEHANNA AND WESTERN RAILROAD.

Based on Topography from Map by U. S. Geological Survey.



and one that we may assume from the diagram was about the center of the sheet it reached a minimum of 2.91. As the western border was approached the density rose again to 2.95.

From these figures it will at once appear that the point of lowest density is the center of the sheet and that the rock becomes heavier as we approach the contacts in either direction. It is also apparent that the change is very gradual for those specimens collected at distances nearer than 300 feet from each other are practically uniform. These would, however, undoubtedly show corresponding variations were their densities determined with very great accuracy.

It must now be noted that as one proceeds from the center of the sheet towards the western border, the density rises again to 2.95 which is just about what one would expect were the sheet conformable to the sediments on its upper contact. That this is true, in this locality at least, is placed beyond doubt when we observe the diabase passing conformably beneath the shales in the excellent exposure at the western end of the New York Susquehanna and Western R. R. tunnel.

Although exposures in other localities have been shown by Darton * to give evidence of a dike which has broken across the strata and fed the sheet which now forms the palisades, certainly at this point no traces of a non-conformity between the diabase and its including sediments can be observed.

External Effects.—While the internal effects noted above are interesting, they are far less noticeable than those produced by the intrusion on the enclosing sediments. The metamorphic rocks which result contain a varied series of minerals which are of considerable interest in themselves but much more so when viewed in their relation to the intrusive nature of the diabase. Owing to the limited nature of the exposures and the distance to which the metamorphism has extended the writer was unable to obtain any of the unaltered shale from the immediate vicinity of the diabase. Osann, however, described unaltered shales taken from the West Shore Railroad tunnel when the latter was first opened. These he describes as follows:

"The unaltered shales are very fine-grained and almost black; they owe their color to a very fine-grained coaly pigment which may be driven off by ignition, whereby the rock assumes a dirty

* Bulletin U. S. G. S., pp. 37, 41, 72, et. al.

brown color. They consist of a fine fragmental aggregate of feldspar and quartz with chlorite and mica. Clay-slate needles (ruttle) are entirely lacking." Besides these shales the other original, unaltered sediments may be assumed to be approximately the same as those strata of the Triassic formation which appeà at some distance from the Palisades, *i. e.*, sandstones of a more or less feldspathic character and various gradations between these and argillaceous shales.

The metamorphic rocks produced from these by the intrusion of the diabase can be divided into nine divisions, four of which have been studied and described by Andreae and Osann and the remain der by the writer.

A short summary of Andreae and Osann's work is set forth below. They describe the contact products as follows:

1. Normal hornfels such as is typical of any plutonic contact.
2. The same rich in tourmaline.
3. Contact rock probably derived from arkose and containing green hornblende.
4. Lime-silicate-hornfels.

The first two divisions are dense brown to dark-gray rocks, rich in biotite, Division No. 2 containing numerous tourmaline prisms lying parallel, at an angle and perpendicular to the lamination. The tourmalines are zonally built and of a transparent gray to reddish-brown color. The main body of the rock is feldspar, mostly plagioclase, but with considerable unstriated feldspar. Quartz is entirely lacking.

Division No. 3 looks much like buchite. Quartz and feldspar comprise the body of the rock and encroach on one another in the manner characteristic of hornfels. To these may be added green-shredded hornblende and isolated grains of zircon.

Division No. 4, or the *Lime-silicate-hornstone* consists of colorless pyroxene related to diopside, of tremolite, garnet, vesuvianite, epidote, biotite, some feldspar and titanite together with calcite. Alternating bands of different colors depend upon the predominance of diopside in the lighter and biotite in the darker layers.

These four classes of altered shale were all obtained from exposures on the lower contact of the diabase. Of the other five classes the first three were collected by the writer from the new lower contact exposure at Shady-Side, New Jersey, and the last two from the upper contact at the western end of the New York, Susquehanna and Western Railroad:

Lower Contact.

1. Normal hornfels rich in spinel.
2. Lime-silicate-hornfels containing brown, basaltic hornblende.
3. Normal hornfels containing "augen" and layers composed almost wholly of green hornblende.

Upper Contact.

4. Hornfels containing richly scattered crystals of andalusite.
5. Arkose hornfels containing the same.

Division No. 1, or the hornfels rich in spinel, was obtained only in a layer about six inches in thickness and in immediate contact with the diabase. The rock is very dense and is composed of feldspar in somewhat subordinate amount and in exceedingly fine grains, and of biotite. The biotite is in very small irregular scales and constitutes almost the whole body of the rock. The spinel occurs in irregular grains and crystals of approximately 0.16–0.12 mm. in diameter. The crystals usually show only the octahedron but the rhombic dodecahedron may be seen on some of them, modifying the edge of the first form. They appear macroscopically as dark dots and might easily be mistaken for magnetite. Under the microscope, however, they show a dark bottle-green color and are probably of the iron-alumina variety, hercynite, although some magnesia might very well be present in a rock so rich in biotite.

Division No. 2 is an exceedingly interesting rock and contains a variety of minerals. It is practically a lime-silicate-hornstone as described by Osann, the main body of the rock being composed of colorless diopside. The rock grades gradually towards the normal hornfels type by an increasing amount of minute scales of biotite and of feldspar grains. Examined in the hand-specimens dark scales of what appears to be biotite are seen scattered through the rock, entirely independent of the original bedding in their orientation. When examined under the microscope, however, these prove to be masses of brown basaltic hornblende. They seldom show crystal boundaries. Frequent cross sections show the very clear cut cleavage characteristic of this variety of amphibole. The absorption is very strong, being light brown with a slight violet tinge parallel to a and a very dark, almost opaque brown parallel to c. The extinction angles are so low that measurements can rarely be made. The most typical feature in the occurrence of this mineral, however, is in its relation to the biotite.

The latter mineral always surrounds the hornblende in a greater or less amount, sometimes being almost lacking and again forming an irregular mass in which only a small plate of hornblende is visible. It is never in hexagonal plates, but in large irregular masses which encroach on the hornblende and obscure its crystalline boundaries. The flakes of hornblende vary from 3 mm. in diameter down to those which may be only distinguished under the microscope as dark specks; the majority of them are, however, quite large, while microscopic masses are lacking. They are distributed very thickly through the rock and the layer containing them is about eighteen inches thick, continuing with great regularity throughout the exposure. Besides this mineral three others of interest may be noted in this rock, namely augite, sillimanite and apatite.

The augite is in a separate layer, which is somewhat indistinctly marked off from the rest of the rock by a thin and irregular band of a more basic nature than the main mass. It occurs in distinct crystals, which exhibit the characteristic cleavage, high relief and interfence colors of augite. It may be distinguished from the diopside which makes up the main body of the lime-silicate-hornstone by the fact that it occurs in comparatively large and distinct crystals, while the latter is not known to occur in these rocks, save in small, irregular masses, only distinguishable with the high power. It forms the larger part of the layer in which it occurs, radial masses of fibrolite also appearing in great abundance, sometimes attaining a quite considerable size. Biotite, chlorite and some feldspar make up the rest of the layer.

In the more biotitic phase of the rock or that showing a gradation towards the normal hornstone, clusters of apatite crystals may be made out. These are well crystallized and occur together with masses of magnetite against which the hexagonal cross sections show very distinctly.

Division No. 3 is merely a variety of hornfels of a biotitic nature containing *augen* and some continuous layers of hornblende. It seems to be quite distinct from Osann's "Hornfels with shredded green hornblende," for the latter is to be referred to an original arkose, while the rock in question is of the normal hornfels type. The *augen* and layers are marked off from the rest of the rock by veins of biotite in very small irregular masses. They are composed almost wholly of a brownish-green hornblende. This shows strong pleochroism brownish-green parallel to c, and brown-

ish yellow parallel to a. Much chlorite and some feldspar are present in these layers.

Divisions Nos. 4 and 5 which grade into one another may be described together. They were the only rocks obtained from the contact above the diabase that proved of special interest. They are dense greenish-gray to greenish-black rocks with irregularly banded portions of light pinkish-gray color due to the prevalence of feldspar. Disseminated thickly through them may be seen crystals of andalusite of the chiastolite variety. These are from 1–4 mm. in length and ⅓ as long as broad. Cross sections of a roughly rectangular appearance are also noticeable. When the rock is cut into sections these may be seen to have the characteristic hour-glass structure of andalusite. Under the microscope they prove to be very imperfect crystals and are evidently only in the incipient stages of crystallization.

The hour-glass structure is very clearly brought out, however, by the great mass of symmetrically arranged inclusions which are for the most part small grains of magnetite. A very noticeable feature of the crystals is the clear rim surrounding them. The main body of the rock contains much magnetite and biotite, but in this rim these are almost entirely absent, having been apparently extracted from it by the crystallization of the mineral. Around the crystal, between it and the clear rim are generally arranged large grains of magnetite like a necklace. The optical properties of the mineral can hardly be made out owing to the great mass of inclusions. It seems to occur in the more feldspathic phase of this hornstone in as great profusion as in the darker portions, although the crystals are of somewhat smaller size.

The writer is unable to find in the literature any mention of andalusite as a mineral of diabase contacts although it is exceedingly common in contacts of granite and other plutonic rocks. It is worthy of note that a mineral so typical of plutonic contacts should be formed in the upper limit of the intrusion. Indeed, from a petrographical standpoint a more convincing proof of the intrusive nature of the rock could scarcely be desired.

In addition to the andalusite hornstone all of the varieties of metamorphic rock mentioned by Osann with the single exception of that carrying tourmaline were also formed on the upper contact of the sheet. In both contacts the effects extend without doubt to a great distance beyond the limits of the exposures, for no decrease

in the degree of metamorphism can be detected at the farthest distance from the trap at which the sediments are visible. The absence of tourmaline, spinel, basaltic hornblende, apatite, fibrolite and augite from the specimens collected in the upper contact would seem to indicate that the metamorphic agencies were more active on the lower than on the upper border of the sheet, but the great abundance of andalusite—a mineral indicative of great metamorphic activity—is somewhat at variance with this. On the whole the rocks above present no great differences from those below so far as completeness of alteration is concerned and it is not impossible that the absence of these particular minerals from the upper contact may be due more to the original composition of the enclosing sediments than to a lesser activity of metamorphic agencies. The presence of andalusite above certainly shows that the contact effects here must have been very great as does the fact that the hornstone at 100 feet from the upper contact is baked as hard as any that appears below the sheet.

We may sum up the chief points of this paper as follows:

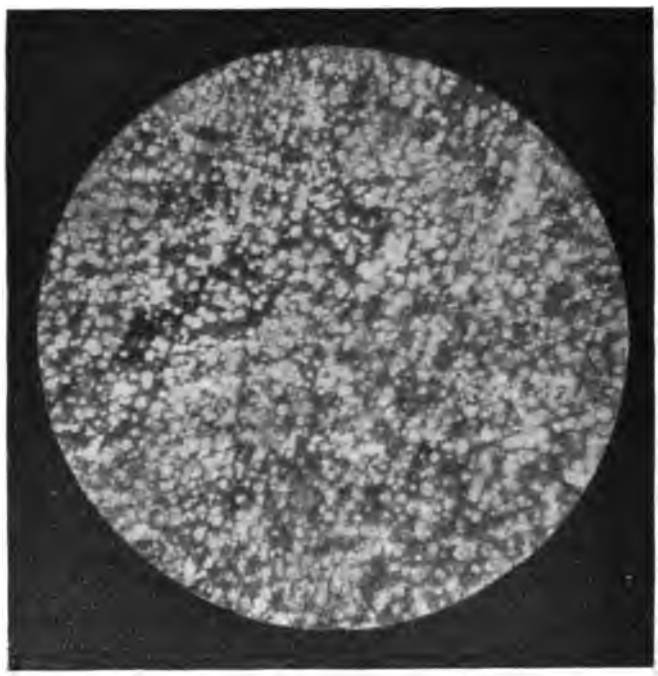
1. The diabase shows in addition to an increase in fineness of grain, a regular increase in density as we approach the contacts.

2. The conformity of the diabase to the overlying sediments, as well as the increase in density towards its western border, seem to give evidence of a conformable contact above and below.

3. The presence of andalusite in the upper contact confirms the conclusion of Darton and Osann as to the intrusive character of the Palisades.

In addition to the above interesting features of this contact the writer submits a few notes on a specimen of supposed leucite rock, which was not determined with sufficient certainty to be incorporated among the contact rocks mentioned above. The specimen referred to was collected in the eastern end of the tunnel by Professor Kemp some years previous to the writing of this paper, and was handed to the writer together with some other specimens collected at the same time. Microscopically it resembles the ordinary biotite hornstone, but is of a slightly lighter gray color, and presents a fine mottled aspect, as if covered with very faint spots about the size of a pin-point. Under the microscope it shows an aggregation of almost circular masses of a transparent character sometimes showing the octagonal outline of leucite, and again verging towards a hexagonal form. (Fig. 1.) With crossed

FIG. 1.

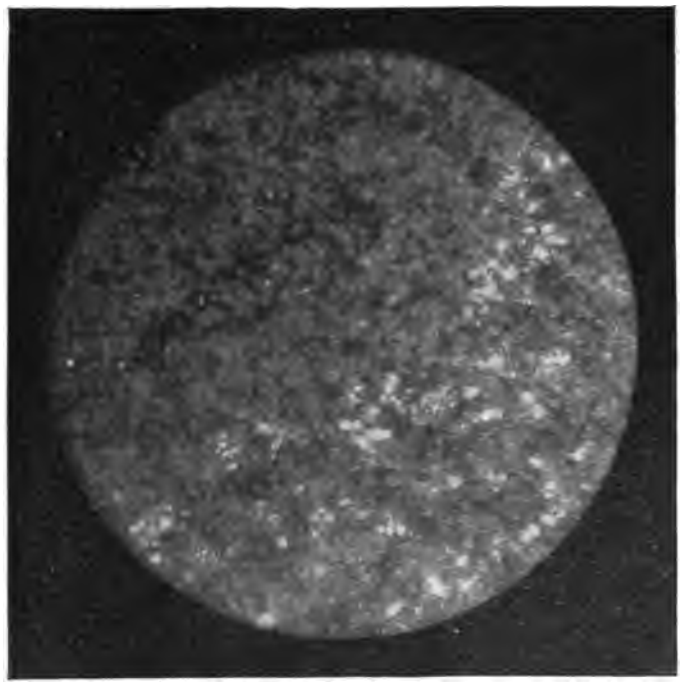


WITHOUT CROSSED NICOLS.

nicols the effect shown in Fig. 2 is produced. The clear circles are extinguished almost completely, except where inclusions of some doubly refracting material have allowed a small portion of light to penetrate the plate. Upon analysis it was found that the rock did not produce gelatinous silica, thus barring out analcite as a possible explanation. The complete analysis is given below:

Contact Rock.		Leucite.
SiO_2	54.13	55.0
Al_2O_3	31.93	23.5
CaO	1.75	——
MgO	trace	——
K_2O	8.17	21.5
Na_2O	3.39	——
Fe_2O_3	0.89	——
	100.26	100.0
Specific gravity = 2.74.		Specific gravity = 2.45 — 2.50.

FIG. 2.



CROSSED NICOLS.

A glance at this analysis shows that while the percentage of silica is correct for a rock composed largely of leucite, the alumnia and the soda are too high, while the potash is much too low, for the theoretical composition of that mineral. When we consider, however, that there is much interstitial matter between the isotropic masses it becomes easier to account for these discrepancies. The difference in specific gravity may possibly be due to the same cause.

While the writer would hesitate to pronounce the mineral leucite, the more so as such has not previously been known as a contact mineral, it is a little difficult to suggest any other satisfactory explanation of the observed phenomena.

The writer takes great pleasure in expressing his acknowledgements to Professor Kemp for many valuable suggestions during the preparation of this paper, also for facilities for investigation kindly placed at his disposal by the gelogical department.

THE APPLICATION OF ELECTRICITY FOR WORK IN COLLIERIES.*

By CLIFFORD R. BUCK.

In the following pages an attempt has been made to give briefly and clearly some ideas as to current practice in the use of electric power for colliery installations. As the subject matter was originally presented in the form of lectures, and it was necessary to cover the ground within two hours, many details have been unavoidably omitted.

Power Plants.

In looking into the design and construction of a power plant for use of collieries, it must be remembered that though the requirements are very similar to those to be met with in street railway practice, as regards fluctuation of load and regulation of speed, the economic conditions are entirely different, since the question of cost of coal and water is not considered at all, and that of space but rarely. It will be found, therefore, that in the average mine plant no attempt is made to economize fuel or water, by the use of condensing or compound engines, or any of the methods used in the ordinary street railway plant. At first sight this may seem bad practice, but when one remembers that the fuel used under the boilers is often an unsalable product that would have to be burned in any case to be disposed of, the apparent extravagance is justified.

As to space requirements that would make the use of the direct connected unit necessary, it may be said that these are rarely operative, except where it is desired to increase the present capacity without crowding the machinery. The latter case would hardly arise, since almost all power houses are erected with the idea that the first installation shall be duplicated. The direct connected unit is also higher in first cost than the belted unit of the same capacity, and requires a higher grade of attendance. For these reasons it will be found that the belted unit is by far the most common. It is seen, therefore, that the question of what units shall be chosen to make up the plant will be decided largely by first cost coupled with the merits of the machinery under consideration. In general, it will be found that the engines are high speed,

* This article is printed from the notes of two lectures delivered by Mr. Buck at Columbia University, December 13 and 15, 1898.

with automatic cut-off, running on not over 90 pounds of steam. The generators in the majority of cases are of the multipolar type. The boilers are of the fire tube type. The tendency at the present time is to make the unit of power for colliery work 100 K. W.

The choice of make of machinery is usually left to the mine operator, estimates being made for as many different combinations as may be desired. Of the different makes of engine on the market the McEwen seems to take the lead, followed by the Erie Ball, Ideal, Erie and Skinner. Of generators the Eddy seems to be the favorite, though almost all makes are represented. The boilers are of any good type, and are usually specified by the company furnishing the machinery. The voltages generally employed in colliery service are 220, 250 and 500, the majority being of 220 and 250, as most mining men consider these pressures to be less troublesome to the stock than the 500-volt system, the miners being, at the same time, less afraid of the lower pressures. Of course the choice of pressure will depend on the distance the power is to be transmitted, the cost of copper in this class of work being one of the largest items. A drop of pressure of 10% is that usually figured on, but this is greatly exceeded in some collieries, due to lack of feeders.

It may be well at this point to give a list of the machinery in use at a few different collieries, together with the efficiencies, where these have been obtained.

Norfolk Coal and Coke Co., Maybeury, W. Va.

Two 100 H.P. boilers, one 125 H.P. McEwen engine, one 75 K.W. Link Belt generator (bipolar), 250 volts.

These furnish power to: one 60 H.P. L-B locomotive, two 15 H.P. chain mining machines, one 15 H.P. Larry motor, one 3 H.P. pump motor, one 2 H.P. motor driving emery wheels.

Knoxville Iron Co., Briceville, Tenn.

Two 100 H.P. boilers, one 175 H.P. McEwen engine, one 100 K.W. Eddy generator (4-pole), 250 volts.

This plant furnishes power to: six 17 H.P. Jeffrey chain mining machines, one 1.5 H.P. Jeffrey coal drill.

Mt. Lookout Colliery, Wyoming, Pa.

One 150 H.P. McEwen engine, one 100 K.W.G.E. generator (4-pole) 500 volts.

These furnish power to: one duplex pump, 300 gals. per minute, one 50 H.P.G.E. locomotive, 2500 lbs. D.B.P., one 30 H.P.G.E. locomotive, 1500 lbs. D.B.P., a few small drills and lights.

Wheeling, Lake Erie and Pittsburgh Coal Co., Dillonvale, Ohio.

Four boilers (probably of 100 H.P. each), two 175 H.P. McEwen engines, two 100 K.W. Eddy generators (4-pole), 250 volts.

These furnish power to: one 110 H. P. Jeffrey locomotive, and ten Jeffrey chain mining machines.

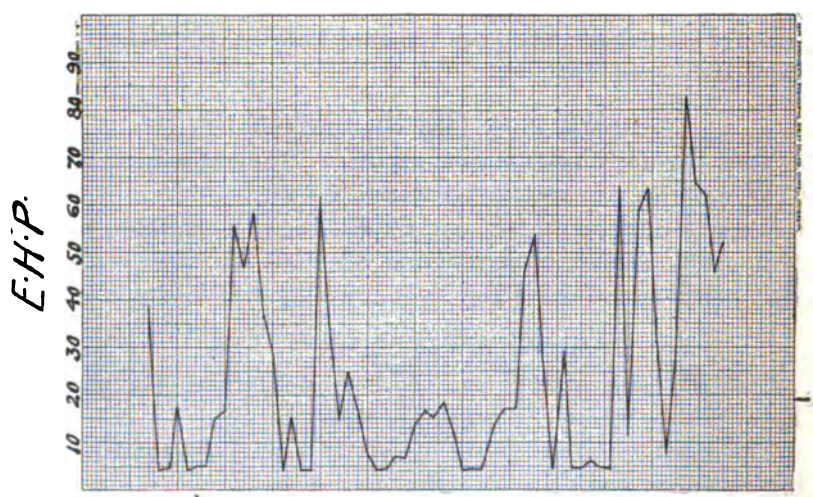
Alma Coal Co., Glen Roy, Ohio.

One 125 H. P. oil engine; one 60 K. W. Eddy generator (4-pole) 250 volts.

These furnish power to: two 20 H. P. Jeffrey locomotives; one 1.5 H. P. coal drill.

It will be noted that the boiler capacity is in nearly every case greater than necessary, which is due to the fact that other machinery takes steam from them at the same time.

An idea as to the character of the load on one of these power stations is given by the curve shown in Fig. 1, which was made



Curve showing variation of load on Power Station. Readings taken every minute.

FIG. 1.

from data taken from the plant of the Norfolk Coal and Coke Co., mentioned above. In this curve it is easily seen that the average load is very small, being actually only about 21.8% for the day. At other plants the same holds true in a greater or less degree, and the probabilities are that the average load on a plant of this kind will rarely reach over 25% of the rating. This is the case in all tests I have seen.

In tests made on the Norfolk Co.'s plant the efficiencies were found to be as follows:

	100 Lbs.	80 Lbs.	60 Lbs.
Boiler,	51.35%	48.75%	52 70%
Engine Thermal,	3.10%	3.71%	4.22%
Engine Mechanical,	86.60%	85.90%	86.40%
Generator,	73.78%	83.05%	74.75%
Boiler and Engine,	1.54%	1.80%	2.19%
Engine and Generator,	61.27%	69.23%	63.00%
Station, Total,	.94%	1.25%	1.38%

In calculating these efficiencies from heat equivalents, a horse power is taken as the expenditure of 2545 B.T.U. per hour. There are three reasons for the low efficiencies, viz: 1. The boilers were driven far below their rating. 2. The average load was small, causing the engine and generator to work far down on their efficiency curves. 3. The load was extremely fluctuating.

In a 12-hour test on the Mt. Lookout plant the results were as follows:

Average efficiency for day	74.2%
Average load	23.8%
Line leakage	.5 H. P.

It is unfortunate that I have been unable to get figures from some plant where the greater part of the load was made up of coal cutters, as in that case the average load would have been higher and the efficiencies also.

The station itself is usually a frame building sheeted with iron, the boilers being as close to the engines as possible, so as to make the steam connections short. The switchboards are usually of the skeleton type, and are placed near the engine in the smaller plants, as this arrangement gives the engineer the least distance to go in tending to the boilers, engine and switches, or circuit breaker, as the case may be.

It would seem that some means could be devised by which the size of the power plants could be decreased, because at the present time they are, as indicated above, about 75% greater in capacity than required by the average load. If the storage battery were in such a form as to be easily portable without being so high in cost as to prohibit its use, it might be offered as a solution of the question, since by this means the plant could be reduced in size and at the same time could be run at its most economical load. Carrying this idea still farther, all wiring could be done away with, since by mounting the batteries on some form of mine car they could be hauled, together with the mining machines,* to the different rooms or breasts to be cut, or could be taken into some room which is near the center of distribution for the mining machines and connected to a short-wiring system from this point. By either method a large saving in copper, over the present system, might be effected. The usefulness of the locomotive would be largely increased also, as by carrying its own source of supply in the shape of a tender, it could go into the rooms and gather its own trips, thus doing away with the mules employed for this purpose.

WIRING.

In a colliery using coal-cutting machines only, the line is, as a rule, all copper, while in one using locomotives as well, the rails are used as the return. The rooms usually are not wired, as the cutting machines are each furnished with a cable of from 150 to 300 feet in length, which is connected to the main wiring when the machine is taken into a room to cut. This cable may be either of the concentric or the parallel-wire type. The parallel-wire type has been found to give the best results in service, since there is not such a tendency for the wires to work together and cause a short circuit. In wiring a mine for either machines or locomotives, special forms of appliances used in street railway and lighting practice are used. The trolley hangers are very short and compact, and are fastened either directly to the roof by malleable iron pins, or else are attached to timbers placed across the entry. These pins are cast in halves, one having projections, the other being smooth. The half having projections is placed in the hole drilled in the coal or slate to receive it, and the smooth half is

* The usual name for the under-cutting machines largely used in bituminous mining. This term is generally used throughout the article.

then driven up beside it, making a very firm support for the insulator or hanger which may be used. When wiring a mine for cutting machines only, the general practice is to keep away from the main haulageways as much as possible, and so the wires are usually taken into the mine on the main air course where practicable, as this lessens the chances of the stock coming into contact with the wires and causing trouble.

In putting in the wiring in a mine, the construction man goes over the route where the wires are to be strung, and marks the places where the holes for the insulator pins must be drilled. These are usually placed one over the other about eight inches apart, the pairs of holes being placed as far apart as the nature of the side of entry will allow. If the entry is straight they may be placed about forty feet apart; if not, they must be closer. When all the holes have been drilled, the pins and insulators are put up, and when this is done the wiring is begun. The positive and negative wires are carried along together. They are first anchored at the power house, and from there are taken over a pole line to the shaft or entry in which they are to be strung. The reel of wire, which is mounted on a hand barrow, is taken up the entry till it is all played out; the men then bring up the other wire in the same manner. While this is being done another gang lays the first wire over the insulators, and puts on the tie wires, giving them a half turn in so doing. The "come along" is then attached, and the wires pulled up taut with a block and tackle. Two men then go over the line with gas pliers and tie, giving five turns each side of the insulator. The other wire is then put up in the same manner. By this time the men who are reeling out the wire will have another length payed out, and this is then spliced to the length which has already been put up. The most common form of splice used is the telegraph splice. Another and a better is the wrapped splice, as it gives more surface contact; it takes longer to make, however.

Where the wires cross the main haulways of the mine the roof is blasted down, unless it is naturally high enough to allow the mules to pass without danger of contact. As the positive wire is always placed up in the corner of the rib, or side of the entry, it is usually out of the way as far as the rolling stock is concerned. In narrow places, or where the entries are very crooked, channelling the rib is sometimes resorted to, but this is rather expensive work.

In wiring for mining machines the ordinary form of round wire is used. In wiring for locomotives there are some differences. The wire is usually of the figure-8 cross-section, which is a great improvement over the ordinary form, since with the latter the flashing or sparkling at the supports is excessive, due to the form of hanger used. With the figure-8 wire the trolley wheel does not touch the hanger, and there is a minimum of flashing, which then takes place only at the switches. The trolley wire in mine work is usually placed over the rail, where an outside wheel locomotive is used, or six inches outside the rail if for inside wheels. A variation of a foot either way is allowable. In putting up the trolley a length is reeled off; this is placed in the supports which are tightened enough to hold it up, the "come-along" is then attached, the wire drawn up taut with block and tackle, and the clamps tightened up permanently. Soldered or clamped joints are used to connect the lengths. On reaching the end of the line the wire is usually anchored by means of an insulated turn-buckle attached to a timber. Switches are placed in the different circuits so that any one of them may be cut out for repair in case a fall of slate from the roof should tear down the wiring. The rails are bonded and cross bonded every 150 feet. The trolley supports are placed at from 25 to 50 feet apart. Lightning arresters are attached to the line where it enters the mine and at the power house. The wiring of a mine is often a rather difficult piece of work, especially in low coal, such for instance as is met with in Ohio and in the Kanawha Valley of West Virginia. The coal in many of these mines is less than three feet in thickness, and the wire being in most cases as large as 0000, is rather stiff to handle in such cramped quarters.

Locomotives.

There are at the present time several types of electric mine locomotives on the market, but in describing those made by the Jeffrey Co. and the Link Belt Co., the ground will have been pretty well covered. In the Jeffrey locomotive (Fig. 2) two motors are used, one on each axle. The frame is supported on the axles through springs. The wheels are of cast iron with chilled rims. The frame being of cast iron, the weight is varied to suit the requirements by having it either cored or solid. The motors are of the enclosed four-pole type, T-tooth Gramme ring armatures being

used in the smaller sizes and series drums in the larger. In the ordinary locomotive, as made by the Jeffrey Co., the motorman is placed in the middle giving him the maximum protection. The controller box and brake are mounted together, the brake rod running through the controller box, so that the motorman has every-

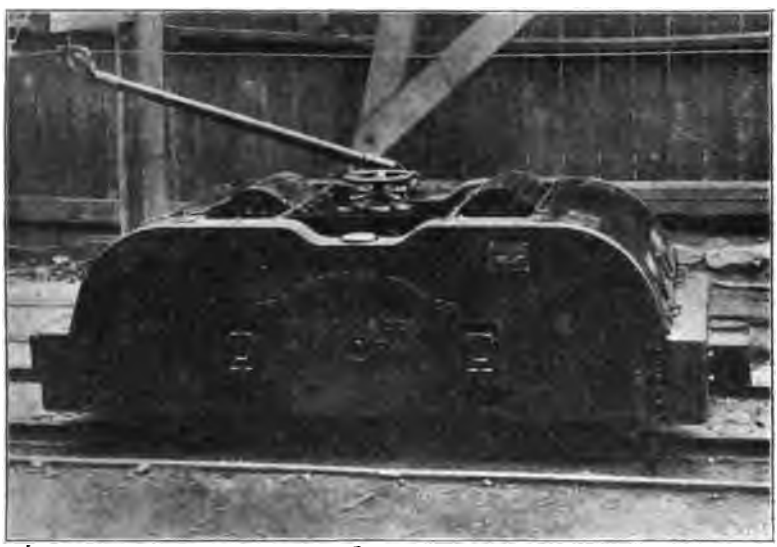


FIG. 2.

thing in the most convenient position for use. The controller is of the multiple break type; that is, the arc is broken on several points at once when the circuit is broken.

The reversing switch is, of course, locked in position, except when the controlling lever is at "off." The controller is usually fitted with an auxiliary series-parallel switch. In the older types this was mounted on the outside of the controller box, but in the latest type it is placed in the box itself. The resistance is made up of iron ribbon wound in coils, the layers being separated by means of a ribbon of asbestos. Ten coils are mounted on an insulated shaft, and are separated from each other by iron spiders insulated with mica. Two of these sets of resistance are mounted on a locomotive. The trolley pole has an automatic catch, so that when it is pulled down it stays in that position till released. The trolley head is of an improved type, and being swiveled allows the

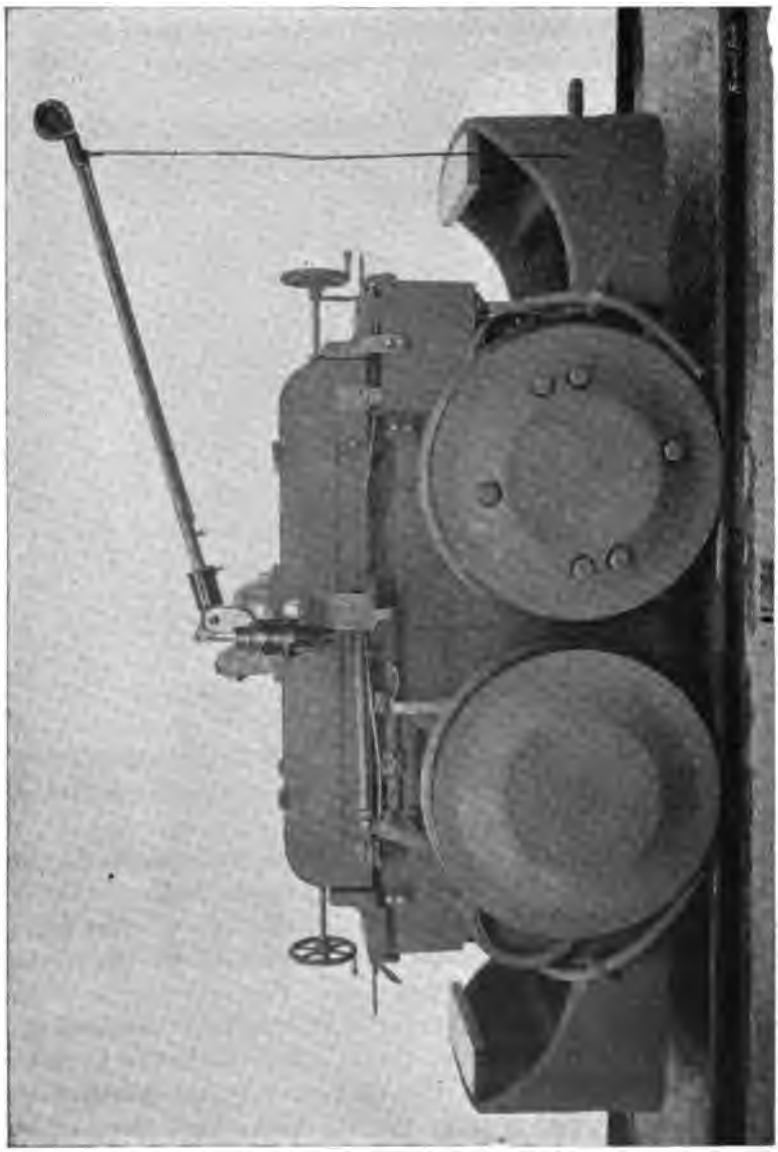


FIG. 3.

wheel to follow the wire much better than the old style of rigid head.

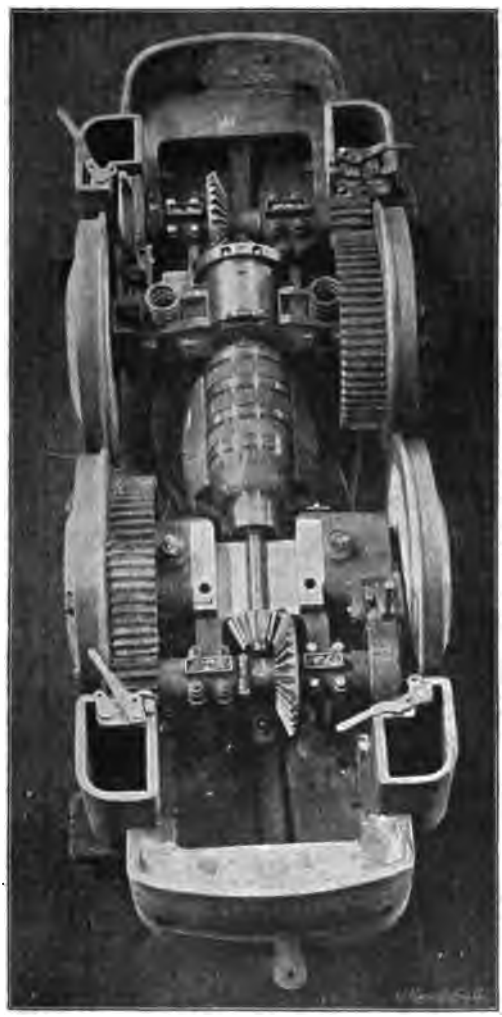


FIG. 4.

The locomotives are made in several different sizes, from 20 H. P. up to 100 H. P. The 100 H. P. locomotive is made with two or three pairs of wheels, as may be called for. In the former case two 55 H. P. motors would be used, and in the latter three 35 H. P. motors, one on each axle. The majority of locomotives

as made by the Jeffrey Co. have inside wheels. For headlights either oil or incandescent lamps are used, and those are mounted over the bumpers, one on each end.

The Link Belt Co. put out a locomotive that is different from anything on the market. (Figs. 3 and 4.) In this machine the main frame is made up of the motor field casting, there being only one motor. The armature is mounted with its axis parallel to the track, and this is geared to both axles through bevel gears and pinions. This method of gearing does not permit the use of springs between the wheels and frame. The advantage claimed for this method is, greater power at starting than where two motors are used, unless the wheels are connected by side rods or some such device. The wheels, as made necessary by the design, are outside the frame, and are of cast iron with soft steel tires. The motor is a series wound bipolar, and is not enclosed. The armature is a surface-wound drum. The motorman can run the locomotive from either end; he is well protected by the high bumpers and in position to do his own coupling. The controller is mounted on the side, and is of the simplest form. The arc is, however, broken at one point only. A band brake is attached to the intermediate shaft at each end. The resistance coils, being similar to that used on the Jeffrey locomotive, needs no further description. These coils, of which there are about 25, are mounted on the top of the locomotive on the side opposite the controller. The trolley head is of the ordinary rigid type. A small arc lamp is used as a headlight. It is mounted on top of the frame in the center and is turned in either direction as required. This style of locomotive is made in sizes up to 80 H. P.

Another locomotive which it would be well to mention is one made by the Baldwin-Westinghouse Co. for the Crozer Coal Co., of West Virginia. This locomotive is probably the heaviest and most powerful electric locomotive in use in any mine, weighing 22 tons and rated at 200 H. P. The speed is slow, the motors having double-reduction gearing. Two trolley poles are used, since there is not room to turn a pole of this length in the mine.

In choosing a locomotive, simplicity and ease of repair should be the main considerations. The locomotive should be so designed that it is easy to take the motors out of the frame in case they should need repair. The armatures should be so wound that if a coil were burned out it might be replaced without disturbing the other coils to any great extent.

The operation of repairing must in itself be simple, since the services of a skilled mechanic, or any one with experience in the handling of electrical machinery, are hard to get. The factor of cost of repairs might also come in, to decide between a one- and a two-motor locomotive, as the cost of a spare armature for the former would be greater than for the latter type of locomotive. The commutators should be of good size, the segments being deep enough to ensure a reasonable life with the roughest handling. The field frames of the motors should have openings so that the brushes may be examined, and the commutators sand-papered, while the locomotive is in operation. The frame should be spring-supported over the axles, as this makes the locomotive much easier on the track. The wheels may be either plate or spoked, with chilled or mild steel tires. The axles must be of ample size, since the continued hammering of the joints tends to crystallize them. The bearings may be of the standard locomotive type, or of the M.C.B. standard, the latter being perhaps the cheaper to keep up. The controller should be of the multiple break, or magnetic blow-out type, as these are the only ones which will give much satisfaction with the continuous use that they get. The trolley poles are of wood so that they may be very easily replaced if broken. The catch for the trolley pole and the swivel head are both very convenient, but are not absolutely necessary. In general practice 100 H.P. is the limit for mine locomotives; they are rarely of greater capacity. The majority are between 40 and 70 H.P. The rating should be on output. This question of rating has caused trouble in the past, since a motor rated on input will not develop that amount of power without giving trouble. In tests made on this locomotive it was found impossible to load it to its full capacity, since the trips had to be taken as they came so as to interfere as little as possible with the work. The speed does not come near to its rating, but that was taken, presumably, on a level, while in actual use the locomotive was working on a grade of at least 1% when pulling at all. The draw-bar pull is increased as would be expected. The maximum noted was 5700 lbs., at a speed of 3.5 miles per hour on a grade averaging 2%. The heaviest grade on which this locomotive works is one of 7.6%, hauling a trip of five cars weighing nearly 3.5 tons each. The start is made on a grade.

It has been found by trial that in the average mine 33 lbs. per ton hauled must be allowed at the draw-bar, and 20 lbs. per ton

must be added to this for every per cent. of grade. The weight of the locomotive also must be taken into account. These figures are rather large, when compared with steam and street railway figures, but it must be remembered that the road beds are not to be compared in quality, and that the axles on mine cars are usually rigid with the car body, making them stiff in taking curves while the lubrication is not always of the best. In some mines the approaches and grades are laid with heavier rails than those in ordinary use, and this gives the locomotive an advantage.

Mining Machines.

The most common form of mining machine or coal-cutter in use at the present time is that known as the Chain Breast Machine. In principle all machines of this type are the same. They consist of a chain provided with cutting teeth, which passes around a horizontal triangular frame, whose apex is attached to the motor carriage, the whole travelling in a bed frame, held firm by means of jacks which are screwed up against the face of the coal at the front, and against the roof at the rear. The cutting teeth of the machine are fastened in the chain in such a manner as to act on the coal in three planes, cutting a "kerf"* about four inches in thickness. The chain passes over idler or blank wheels at the front end or base of the triangular frame. This forms the

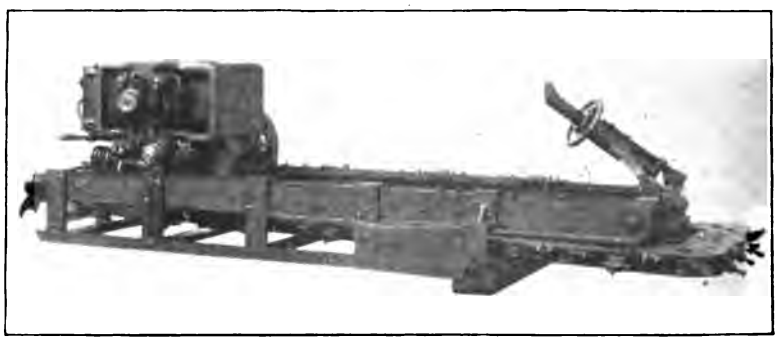


Fig. 5.

cutting head of the machine, and at the rear end or apex the chain passes over the driving sprocket which is geared to the armature. The sliding frame, carriage and motor, are fed forward

*The miner's term for the groove or cut made by the machine.

alongways on the stationary frame by some form of gearing attached to the motor. Two speeds are provided for, slow for running in, fast for coming out, so that the cutting head may be withdrawn from the coal at about five times the speed at which it enters.

It is rather interesting to note the methods employed by the different makers to gain the same end. The machines as made by the Jeffrey Co., and the Link Belt Co., will therefore be described in detail as being representative of this type of machine.

In the Jeffrey machine, Fig. 5, the motor, which is of the consequent pole type, is mounted with the axis of the armature in a horizontal plane, perpendicular to the direction of motion of the

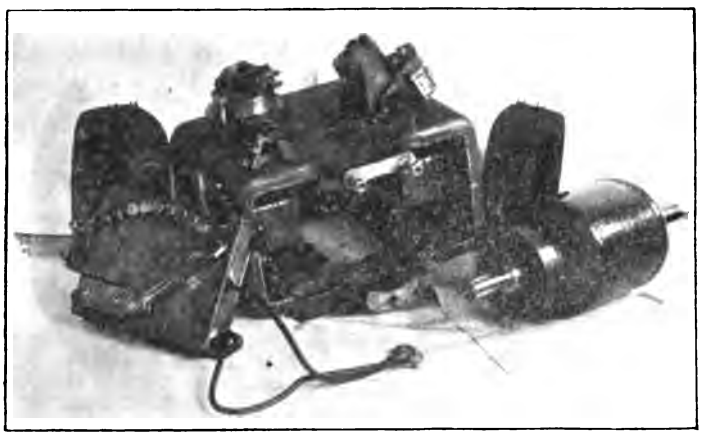


FIG. 6.

cutting frame. The motor, Fig. 6, is shunt-wound, with a T-toothed Gramme Ring armature. The commutator being cross-connected, two brushes only are needed. The motor is rated at 20 H.P. intermittent rating. The field frame and pole pieces are of cast steel, the pole pieces being separate castings, made with a flange on the pole face, the flange being of use in two ways: first, to hold the field coils in place; second, to give a pole horn of gradually decreasing magnetic density.

The field coils are of the mummified type, and are lathe wound. The starting box is of a very neat form. The resistance coil, which is made up of iron and asbestos ribbon wound to form a flat elliptical cake is mounted inside the cast iron box directly behind the

contact buttons. This arrangement makes the box very compact, and gives ample protection to the wiring. The connections are such that the fields are always in circuit as long as the machine cable is attached to the main wiring. This does away with the continual breaking of the field circuit, which is broken only on leaving the room after cutting, so that the liability to damage to the motor due to inductive discharge of the field is greatly diminished. A fuse block is mounted on the back of the starting box, the fuse used being copper wire.

The power is delivered to the chain sprocket from the armature through a gear and pair of bevels. The feed-in and the pull-back mechanism are worked through worm gearing, either motion being thrown in by means of a clutch, which is mounted on the shaft carrying the pinions meshing with the rack on the stationary frame of the machine. The motor with its carriage slides in ways on this frame, and the cutting frame being attached to the motor carriage is fed forward with it, guided by means of a center rail sliding in a guide at the front end of the stationary frame. The cutting head is held against side strain by means of a star wheel mounted in the head and projecting through the top plate

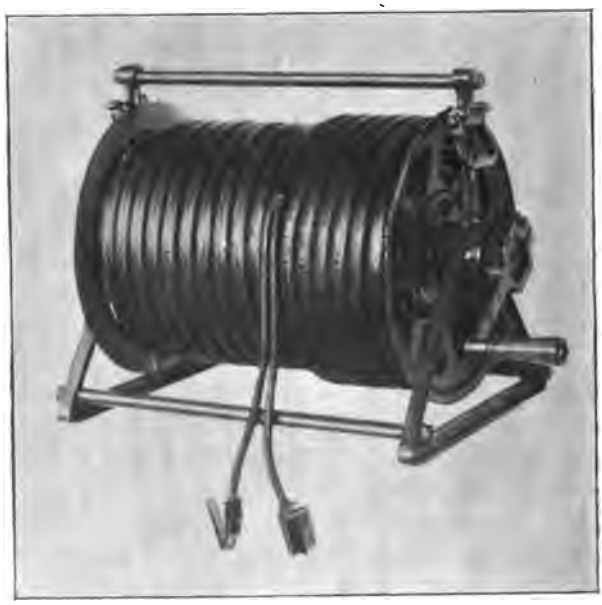
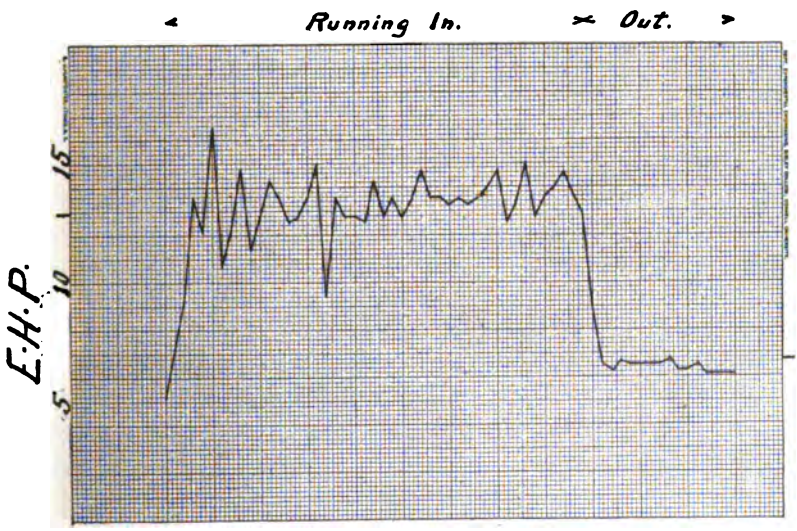


FIG. 7.

The chain, which is quite heavy, has projecting lugs cast on the links, and these three making a set are constructed so that as one points down the next is horizontal and the third points up. Holes are cored in these lugs to hold the cutting bits, which by this arrangement of the lugs may be straight, even though they are to cut in different planes as already stated. An automatic device is used to stop the feed when the carriage has reached the limit of its travel in either direction. The speed of the machines of this make is rather fast. A machine making a 6-foot cut will undercut and come out in about 4 minutes, the width of the cut being 44 inches and the thickness of the kerf 3.5 to 4 inches. The speed of the armature is a little over 900 R.P.M.

Each machine is provided with a truck, skids, crowbars, shovels, bits, oil, tools, a reel (Fig. 7) with from 150 to 300 feet of cable, with snake-head terminals on one end for connection to the main wiring, the terminals at the reel being in the hubs, and a short cable to connect the reel to the machine. This equipment is carried around with the machine on the truck.

The Jeffrey Company makes machines of this type to under-cut 5, 6 and 7 feet as the conditions may require. In weight they will



Curve showing power supplied to Cutter.
Readings every 5 seconds.

FIG. 8.

probably run from one ton to one and one-half tons, depending on the depth of the under-cut, that is, the size of the machine. The weight of the motor alone, for the 17–A machine is 1000 lbs. The motors are wound for the following voltages: 220, 250, 350, 400 and 500. The great majority are for 220, this voltage having been found to be less troublesome to the stock. The men are at the same time less afraid to handle it. An examination of the test curves of one of the motors used on these machines will show that its rating is conservative (Fig. 8).

Turning now to the machine as made by the Link Belt Company, we find one which, though it goes through the same operations, is materially different in design, Fig. 9. In this machine the mo-

FIG. 9.

tor, which is of the bipolar type, is mounted with the armature in a horizontal plane, but the axis is in this case parallel to the direction of motion of the cutting frame. The motor is shunt-wound, with a surface-wound Siemens drum armature. This motor is rated as of 15 H.P. The fields are of cast steel; the upper pole piece is removable so that the field coil is easily gotten at; this is probably wound haphazard. The starting resistance is made up of a number of coils of wire which are mounted on the left-hand side of the motor, and the wires which connect them to the switch are brought over the top of the pole piece to the contacts, which are mounted on a board on the right-hand side.

Power is delivered to the chain sprocket through gears and bevels as in the preceding type. The feed-in and pull-back mechanism are arranged differently, the cutting frame, motor and carriage being fed forward by means of a pawl and ratchet, con-

nected through sprocket wheels to chains fastened to each side of the stationary frame. The pull back is in this case about 4 times as fast as the feed. The total time to run under the coal and come out is about 4.5 minutes for this make of machine. These motions are thrown in at will by means of clutches. The cutting frame is supported by a very low bed frame, in which the motor, carriage and cutting frame slide. The cutting frame is guided by a center rail, as in the preceding form. It will be noted that everything is exposed. Side strain on the cutting frame is prevented by means of a spiral augur mounted horizontally over the top plate and fed into the coal with it, or else one of the idler wheels may be taken out of the cutting head and a sprocket wheel substituted, the shaft of which projects above the cutting head and carries a cutter.

The chain carrying the bits has the lugs and sockets in one plane, so that three shapes of bit are necessary, one bending up, the next down, and the third straight. They are put into the chain in this order, there being about 45 bits on the chain of a 6-foot machine. There is no automatic device on this machine to stop it when it has reached the forward limit of its travel, the runner having to do it by hand. On coming out, however, the feed is automatically stopped. The armature speed of the motor used is 1,320 R. P. M. The time to under-cut and come out is something over 4 minutes for a 6-foot machine, the width of the cut being 42 inches and the thickness of kerf 4.5 inches. The machine is provided with its complement of tools. These are practically the same for all makes, except in minor details. Fig. 10 shows one of the cutters at work. The machines as made by the Link Belt Company are made to under-cut 5 and 6 feet as a rule, the motors being wound for 250 and 500 volts.

Another machine, which is popular in some districts, is that made by the Morgan-Gardner Company. In this machine the motor is mounted so that the axis of the armature is vertical. The frame is similar to that of the Jeffrey.

The amount of power required by a mining machine while making a cut is shown by the following readings which were taken from a Link Belt machine while at work in the Pocahontas coal field, the voltage used being 250.

FIG. 10.

Summary of Coal Cutter Tests.

Hht. of cut, 4.5 ins. Width of cut, 3.5 ft. Depth of cut, 6.08 ft. Sq. ft. cut, 21.28. Armature speed, 1,320.

			Time, minutes.			Electrical horse-power. In,			Out, To overcome friction.				To cut 1		
Run.	Cut.		In.	Out.	Tot'l.	Maxi-mum.	Mini-mum.	Aver-age.	Aver-age.	Feed. On.	Off.		Net to feed cut.	sq.ft.in 1 min.	Volt-age.
1.	a.		5.00	1.15	6.15	15.00	5.15	12.87	6.65	4.30	3.75	0.55	8.57	6.31	263
1.	b.		4.25	1.00	5.25	13.95	4.35	9.60	6.45	4.40	3 75	.65	5.20	5.44	246
1.	c.		4.25	.87	5.12	13.49	5.02	8.77	7.57	4.40	3.75	.65	4.37	5.27	245
1.	d.		4.00	1.00	5.00	12.68	4.02	10.00	7.43	4.44	3.75	.69	5.56	5.49	243
1.	e.		3.87	1.00	4.87	15.40	5.48	10.60	7.28	4.46	3.75	.71	6.14	5.57	247
	Average,		4.26	1.00	5.28	14.10	4.80	10.37	7.08	4.40	3.75	0.65	5.97	5.62	249
2.	a.		4.16	1.08	5.24	13.30	3.98	9.66	5.26	4.43	3.75	0.68	5 23	5.29	258
2.	b.		4.00	.91	4.91	12.08	5.05	8.68	5.98	4.44	3.75	.69	4 24	5.22	259
2.	c.		3 92	1.00	4.92	12.34	4.64	9.33	6 98	4.45	3.75	.70	4.88	5.34	249
2.	d.		4.93	1.08	6.01	11.59	5.56	9.56	6.36	4.31	3 75	.56	5.25	5.52	253
	Average,		4.25	1.02	5.27	12.33	4.81	9.31	6.14	4.41	3.75	0.66	4.90	5.34	253
3.	a.		3.87	.92	4.79	13.85	4.34	9.86	6.42	4.46	3.75	0.71	5.40	5.44	263
3.	b.		3.90	1.00	4.90	10.65	4.10	8 36	5.64	4.45	3.75	.70	3.91	5.17	260
3.	c.		4.08	.92	5.00	13.30	3.26	9.50	5.35	4.44	3.75	.69	5.08	5.41	253
3.	d.		3.85	1.00	4.85	11.40	4.17	8.94	5.20	4.46	3.75	.71	4 48	5.27	253
3.	e.		3.83	.92	4.75	12.05	3 75	9.02	5.64	4.46	3.75	.71	4.56	5 28	249
	Average,		3.91	.95	4.86	12.25	3.91	9.14	5.65	4.45	3.75	0.70	4.68	5.31	256
	Ave. of averages,		4.14	.99	5.14	12.89	4.51	9.61	6.29	4.42	3.75	0.67	5.18	5.42	253

Bits had been running a week when machine was tested.

In working up the results, the item marked—"*To cut one square foot of coal in one minute*,"—is obtained by Hazeltine's formula which is:

$$\text{H.P. required} = \frac{P \times T}{S} - p.$$

Where S equals sq. ft. cut,
P equals net H.P. to cut,
T equals time in minutes,
p equals frictional H.P.

The column, "*net to feed cut*" shows the difference between average E.H.P. and E.H.P. to overcome friction with feed on.

The chain breast machine is in use in mines where the coal is but 28 inches in thickness, and again, in mines where the average thickness is 6 feet, running up to 12 feet in places.

In some mines a great deal of trouble is experienced on account of the obstructions to be met with in the coal, such as black-jack, sulphur balls and clay veins. As these substances are very hard the wear on the bits is greatly increased, making it necessary to change them as often as four or five times a day. In soft coal, such as is found in the Pocahontas district, one of these machines may easily run a week with the same set of bits. The machines are, as a rule, put in with a guarantee to cut so many linear feet of

face per day; therefore, the depth of cut being fixed, the output will vary with the thickness of the coal. If the rooms are wide, as, for example, in Tennessee, where they are 40 feet and over, the machines will have less trouble in meeting their guarantee than where the rooms are only from 15 to 25 feet wide, as in the Pocahontas district, since it is found that the greatest loss in time comes in moving the machine from room to room in the mine, and not in the relative speeds of cutting, though the faster machine would of course show to greater advantage when worked in a wide room than in a narrow one. The greatest number of cuts of which I have record, made by any machine in one day, is 103, and this was made in a mine in the Indian Territory by a Jeffrey 17-A, 6-foot machine, using a self-propelling truck. But this is not a common figure, or one which it is possible to duplicate in every mine.

A general average for machines of this class would be about 50 cuts per day of 10 hours. The speed depends largely upon whether the work is done by contract or by the day.

There are other types of electrically driven mining machines on the market, namely: Shearing and Long-Wall machines.

The Shearing machine, as made by the Jeffrey Co., is merely a chain breast machine, the frame of which is mounted on four standards, the cutting frame lying in a vertical plane (Fig. 11). The axis of the armature is turned through 90 degrees and is in the same position with regard to the frame as is that of the link belt breast machine. The machine is raised and lowered by ratchets, which operate the pinions engaging in the racks on the rear uprights. One cut is made in the center of the room and the coal is then shot from the sides.

The Long-Wall machine is entirely different from the forms described above, the cutting teeth being set in the periphery of a horizontal wheel which is geared to the motor. This wheel is between 4 and 5 feet in diameter. The machine furnishes its own propelling power, drawing itself along the track which is laid for it parallel to the face of the coal by means of a wire rope made fast at some distance from the machine and attached to a drum on the front end of the frame, the drum being geared to the motor. The motor in this type of machine is of the same type as that used on the breast machine, except that it is heavier, of 25–30 H. P. This type is used very seldom in this country, though it is extensively employed in Europe. It has been tried in Ohio to some extent, but with small

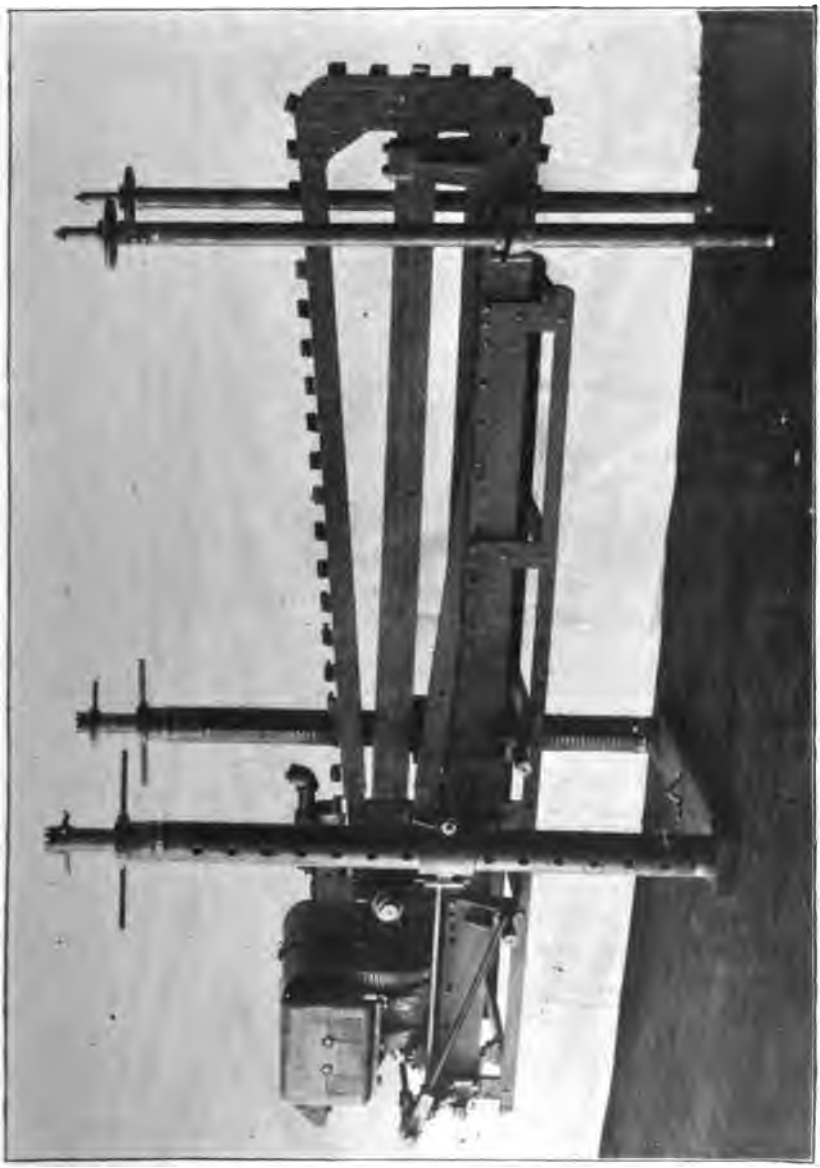


FIG. 11.

success, due to the fact that the coal was not suited to this style of mining. There are some in use in the West that are reported to be doing good work.

The principal points to be considered in selecting any electrically driven apparatus for mine use should be: strength, simplicity, and ease of repairs. In the motor, the armature should be easily accessible, and the field frame should give ample protection from falling slate to the field coils, brushes and commutator. The system of winding should be of the simplest type, so that repairs may be made by men having little experience with electrical apparatus. The starting box should be as compact and as well protected as possible, the fewer the wires exposed to abrasion the better. The insulation throughout should be of the best, since the machines will often have to work in rooms where there is more or less water. As to the machine itself, the chain is apt to give the most trouble.

The self-propelling truck, already referred to in connection with the record run, is becoming quite popular, especially in mines where the coal is thin or the grades bad. Their use makes a few changes in the cutting machine necessary; for instance, there should be a reversing switch for the motor, some arrangement to throw out the gearing which connects the cutting chain with the motor, and a sprocket wheel placed on the hub of the main driving gear.

The following extract from the Chief Mine Inspector's report for the State of Ohio, for the year 1897, is of interest:

Year's coal production, 12,448,822 tons, which is a decrease of nearly half a million over 1896, and one and one-half millions over 1895. Of this 4,106,124 tons were mined by machinery, a gain of 737,775 tons as compared with 1896. 732 men were employed in running the machines, as against 579 in 1896, and 5001 men were employed in blasting down and loading after the machines.

Coal is produced by machinery in 53 mines as compared with 44 for last year; at the close of the year there were 166 electric machines, and 67 compressed air machines.

Electrically Driven Larries, for Charging Coke Ovens.

There are comparatively few of these in operation, but they are doing very good work. It has been found that where an electric motor has been put on a larry, a great saving results in the time taken to charge the ovens, the saving ranging between 2 and

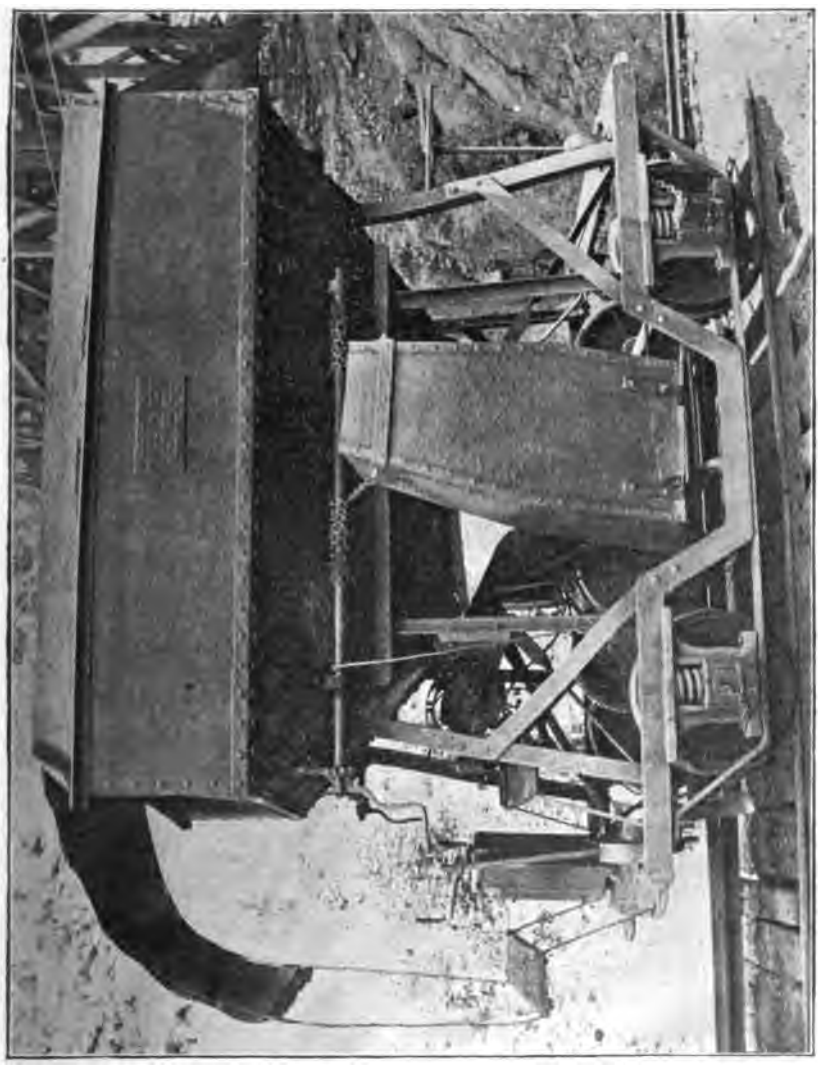


FIG. 12.

4 hours less than where mules were used. The third-rail system can be used to advantage here, since it is very easy to install, especially on a block of double ovens. The third rail is usually placed about a foot from the return rail, and between the rails. This leaves room enough to use a mule in case of a break-down.

In the larry equipment made by the Jeffrey Co., (Fig. 12) one of the standard locomotive motors is used, the field casting being changed in order to admit of the necessary double reduction in gearing. In operation this larry is very smooth, making but little noise. As it runs down grade when loaded, the motor is used only in starting and bringing the empty larry back. The speed is about 6 miles per hour. The third rail is made up of 16-pound mine rails, mounted on wood blocks. Such a larry was equipped for the Pulaski Iron Co., and has been in steady use on their ovens at Eckman, W. Va., since February, 1898.

The equipment furnished by the Link Belt Co., for the same service is somewhat different, the motor being a high speed bipolar, similar to that used on their mining machines except that it is series-wound. In consequence, the gearing necessary to bring the speed down is increased. The motor is mounted on an iron plate resting on the axles, and the trolley is of the common overhead type. The conditions under which this larry is worked are quite severe, as the motor is required to run it loaded up an average grade of 2 per cent. The grade at the start is even heavier than this, and, as it is on a curve, the motor will sometimes take as much as 55 E.H.P. in getting over the knuckle in the track. The motor is rated at 15 H.P. and it was found by test that it took on the average 14.96 E.H.P. to run the loaded larry up the average grade at a speed of a little over four miles per hour. The efficiency at this load is 57.5 per cent. The starting resistance was found to be 1950 lbs. This larry has been in steady use at the Angle Colliery of the Norfolk Coal and Coke Co., at Maybeury, W. Va., for two years, and was the first electrically equipped larry in that region.

Pumps.

The smaller sizes are usually of the rotary type, geared to some make of motor, the motor and pump being mounted on a truck so as to be easily taken to different parts of the mine. There are of course a great variety of types and combinations in use. On

some the automatic starting box will be found, protecting the motor in case the circuit breaker is blown at the power house, but in others no starting resistance is used at all, even though the motors are shunt-wound. As the pumps are usually left to care for themselves, unless they are stationary, and of large size, as will be found in some mines, a safety device of some sort should always be used. The motors used in the smaller sizes are usually entirely enclosed, and are practically water tight. In the small rotary pumps a great loss in efficiency due to slip of the water past the plungers is noted. In a small pump of this type, with a capacity of 50 gallons per minute against a total head of 51 feet, it was found that the slip was 30 per cent. of the plunger displacement, and the efficiency was 24.8 per cent.

The larger sizes of pumps are usually of the geared triplex plunger type.

Bit Grinders.

These are for sharpening the cutter chain bits, and usually consist of a small enclosed motor having an emery wheel mounted on each end of the armature shaft. This makes a very handy tool, since it can be placed in the blacksmith shop where it would often be inconvenient to run shafting. The emery wheels are usually 10 x 2 inches, making about 1900 R.P.M. By trial one of these was found to remove .28 of an ounce of wrought iron per mile run of rim. In dressing up the bits for the cutting machines it is very valuable.

Coal Drills.

Another piece of apparatus quite common in collieries is the power coal drill (Fig. 13). In its usual form this is run by a small bipolar motor, the motor swinging in trunnions on a support which is braced against the roof and bottom of the room where the drilling is to be done. The feed bar which holds the spiral twist augur is threaded and runs through a feed nut, being revolved by the gear wheel through a feather which slides in a slot on the feed bar. A friction band is placed around the feed nut casing, so that if the augur strikes any hard substance it will not feed, but will slip, and so prevent breakage.

The weight of the motor used on one of these drills, as made by the Jeffrey Co., is between 60 and 70 lbs. The rated H.P. is 1.5, at a speed of 2000 R.P.M., and the efficiency of the motor at this

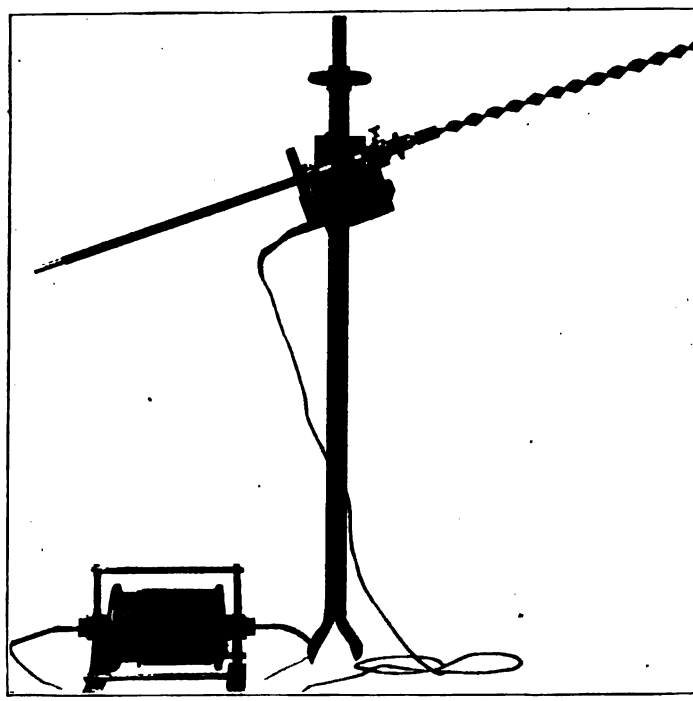


FIG. 13.

output, 73%. The maximum efficiency for the motor is 75% at a brake load of 2 H. P. Three lengths of drill are used in putting in one hole, as this arrangement permits the use of a shorter feed bar than would be otherwise necessary. The drill is furnished with a light truck, cable reel and extra augurs. It is usually run by two men, though one man can operate it if necessary. Speeds of one foot of hole, 2⅝ inch diameter, in ten seconds, are easily attained in good bituminous coal.

NOTES ON TELEGRAPHY AND TELEPHONY.

By W. H. FREEDMAN, E.E.

(Continued from page 193, Vol. XX.)

Receivers.

The original receiver as constructed by Morse consisted of a uniformly moving strip of paper; above this a wooden pendulum was hung so that a pencil fastened to its end was in constant contact with the paper, and drew a straight line on the latter as long as the pendulum was at rest. An electromagnet in circuit with the line, whenever energized, attracted an armature of soft iron fastened to the pendulum which was thereby moved in a direction at right angles to the motion of the paper. The combination of these two motions caused the pencil to mark a zig-zag line whose form varied with the number and duration of the "makes" in the circuit, corresponding exactly to the shape of the saw-teeth type in the port rule of the automatic transmitter.

Following these lines the Morse register was developed. Although now practically restricted, in this country at least, to district messenger and fire alarm service it was the receiving instrument used to the exclusion of all others till the method of receiving by sound was adopted. In this instrument the strip or ribbon of paper, taken from a roll, passes between a pair of grooved rollers whose motion, controlled by clockwork, draws it along at a uniform rate. An electromagnet, overcoming the force of a retracting spring, attracts its armature carried by a horizontal pivoted lever. This lever is armed at the extremity with a style or point of hard steel that works in a groove in the upper roller. Accordingly, a raised line is embossed upon the upper surface of the paper whenever the marking point is forced into the groove by the action of the electromagnet. It appears as a dot or a dash, depending upon the length of time the circuit is closed.

The ink-recording register is a modification of the embossing register, employing an ink-wheel instead of a steel point to record the message. It has the advantage that the ink record is much plainer and easier to interpret. Besides being used in this country it is employed in the British Postal Telegraph Service.

The Sounder.—The instrument from which the message is read,

in exclusive use in the United States on commercial lines to-day, is technically called the sounder. Its essential parts, as shown in elevation in Fig. 18, are an electromagnet *E*, and an armature *A* fixed

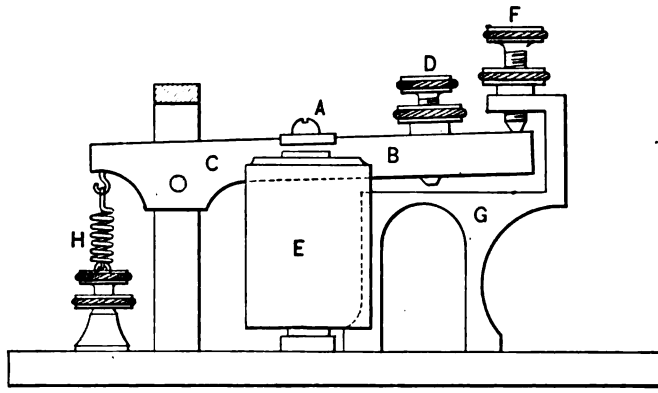


FIG. 18. Elevation of Sounder.

transversely upon a brass lever *B*, fitted with trunnions at *C* and mounted between transverse set-screws in the same manner as the Morse key. Two other set-screws *D* and *F* form adjustable stops,

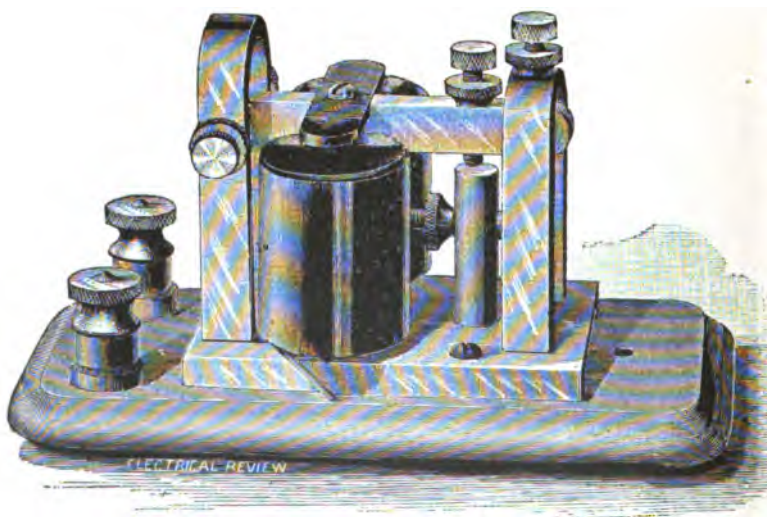


FIG. 19. Sounder.

which limit the vertical motion of the lever in each direction. When the circuit is closed through the electromagnet, the arma-

ture is strongly attracted and the set-screw *D* is thereby made to strike forcibly against a sounding-post or bridge *G* through which the vibration is imparted to the base of the instrument, thus amplifying the sound. When the magnetism disappears, the lever is thrown against the upper stop *r* by the recoil of an adjustable spring *H*. If the time between the down-stroke and the up-stroke is so short as to practically merge the two sounds into one, it forms a dot. When, however, the two sounds are distinct, then a dash is intended. Fig. 19 gives a perspective view of a common pattern of sounder.

Construction of Telegraph Magnets.—The electromagnet of a telegraph sounder should be constructed along lines governed by these two considerations:—

1. Maximum attractive force for a given current.
2. Quickness of action.

The attractive force exerted by an electromagnet when it is energized by any given current will depend upon the distance of the armature from the poles and also upon the magnetic circuit. The variation of the attractive force with the distance of the armature from the poles is well shown in experiments* made with an electromagnet having a core formed from a round bar 19 inches long and 1 inch thick, bent into a horse shoe, with its poles 1.25 inches apart. The distance of the armature from the poles was determined by the interposition of sheets of rolled brass .00416 of an inch thick, the required number of these sheets for each experiment being strongly pressed together and soldered at the edges. The following table gives the results in weights lifted, with various thicknesses of brass sheets numbered from 1 to 10, interposed between the magnet and the armature, while the corresponding curve is plotted in Fig. 20. The rapid increase in the attractive force as the armature approaches the poles of the magnet is shown in a striking manner.

Distance.	Weight Lifted, Grains.	Distance.	Weight Lifted, Grains.
0	82,000	6	11,300
1	35,000	7	9,300
2	25,000	8	7,400
3	20,000	9	6,500
4	15.500	10	5,500
5	12,100		

* Daniel Davis, Jr., Manual of Magnetism.

The distance of the armature from the poles being fixed, the attractive force will vary with the flux produced, which in turn for a given current depends upon the reluctance of the magnetic circuit. The iron portion of the magnetic circuit should therefore be built of the very best soft iron and be of proper dimensions.

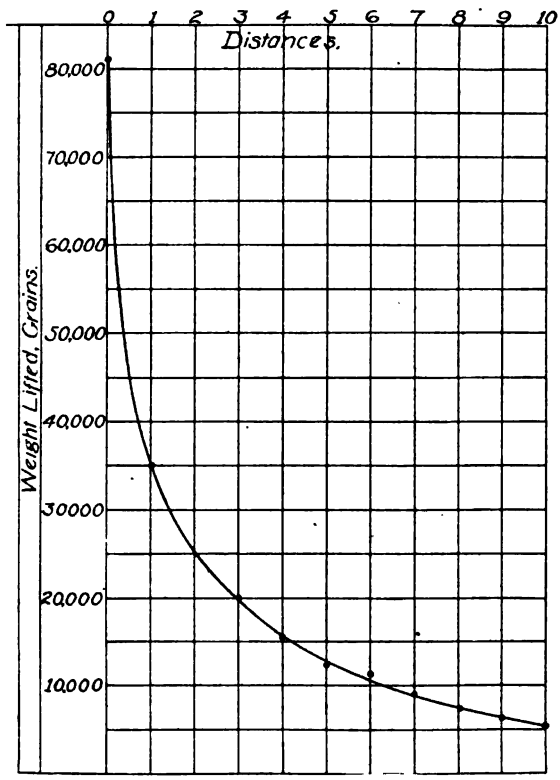


FIG. 20. Decrease of Magnetic Attraction with Distance.

The quickness of action will depend upon the self-induction in the circuit, the eddy currents induced in the core and the hysteresis of the iron. Expressed in absolute units the coefficient of self-induction of a coil is the number of lines of force threading through that coil when the current flowing is unity. Now, since number of lines of force cut per second gives voltage, the coefficient of self-induction of any coil is, in practical units, its counter E.M.F. when the current varies at the rate of one ampere per second. It therefore always opposes change of current. For instance, on

closing a circuit the current does not immediately have a value given by Ohm's law, but, as shown by Helmholtz, follows the law

$$C = \frac{E}{R}\left(1 - e^{-\frac{R}{L}t}\right)$$

where C = the current in amperes.
E = the voltage of the circuit.
R = the resistance in ohms.
L = the coefficient of self-induction in henries.
t = the time in seconds after the circuit is closed.
e = the base of the Naperian system of logarithms.

Theoretically the current only reaches its value corresponding to Ohm's law after an infinite time. Practically this may mean several seconds or in an extreme case perhaps a minute or so. This phenomenon is shown graphically in Fig. 21, in which there are two curves of rise of current with the values calculated from Helmholtz's equation tabulated in the upper left-hand corner.

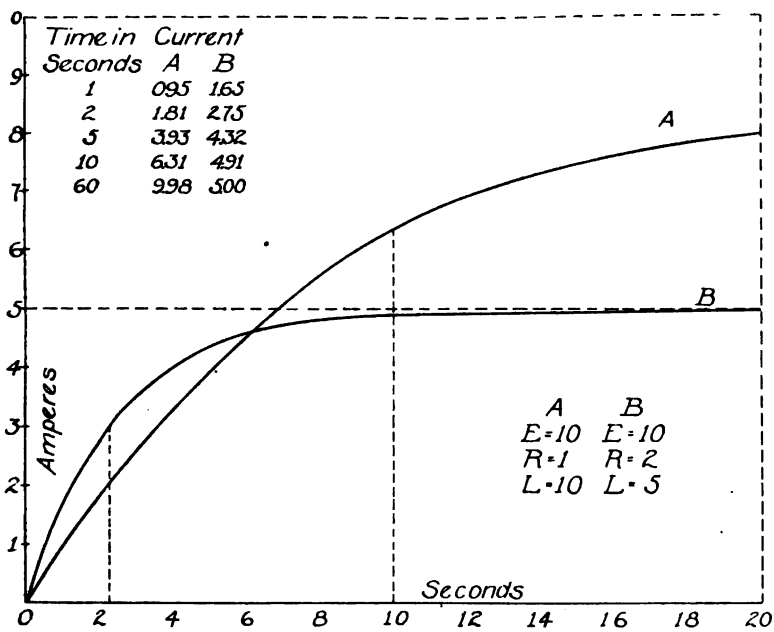


FIG. 21. Rise of Current.

Consider a circuit having $E = 10$ volts, $R = 1$ ohm and $L = 10$ henries. The steady current will be 10 amperes; but at the end of one second the current is only 0.95 of an ampere (see curve A).

At the end of a whole minute it is only 9.98 amperes. Suppose now we increase the resistance to 2 ohms and reduce the self-induction to five henries. The final value of the current will be only 5 amperes instead of 10; but it will rise more quickly (see curve B). At the end of one second it will be 1.65 amperes and remain greater than in the first case until about six seconds have passed.

Now consider a telegraph magnet. If the circuit is not kept closed long enough, the current will not rise to a high enough value to produce sufficient attractive force to overcome the retracting spring and absolutely no motion of the lever is produced. As the length of a dot is only a fraction of a second, it is at once apparent that the self-induction must be kept low.

The eddy currents induced in the iron due to changing the flux will be always opposing the change of the flux and, therefore, a lag will result so that the induction will be a short time behind the magnetizing current. This is further increased by the hysteresis of the iron or the lagging behind of changes in magnetic intensity to changes in magnetizing force. When a mass of soft iron, such as the core of an electromagnet, becomes enveloped in a magnetic field, an appreciable time elapses before it acquires the maximum intensity of magnetization which the field is capable of producing. On the other hand, when the iron is withdrawn from the field, or, what is the same thing, the field is withdrawn from the iron, the latter does not lose its magnetism instantaneously; the magnetism falls off in a similar way to that in which it increased, and in almost every case some small quantity of magnetization will remain for some time, and possibly for ever, after the separation of the iron from the field. This is termed remanent, or more commonly residual magnetism. In some brands of cold-blast charcoal iron, when carefully annealed, such as Norwegian, Swedish, and Lowmoor iron, scarcely a trace of residual magnetism remains, and these irons are therefore preferred in the manufacture of magnet cores. Experiment has also shown that the shape of the core is no less important than its quality, and that quickness of action and freedom from residual magnetism may be best secured by making the cores as short as possible.

From these considerations the best proportions to give to a telegraph magnet is hardly a matter of guess work. Fig. 22 is the section of what may be called a standard telegraph magnet whose proportions approximate closely to those most commonly used at

the present day in the United States. The iron portion of the magnet is of the best soft iron and consists of the following parts:

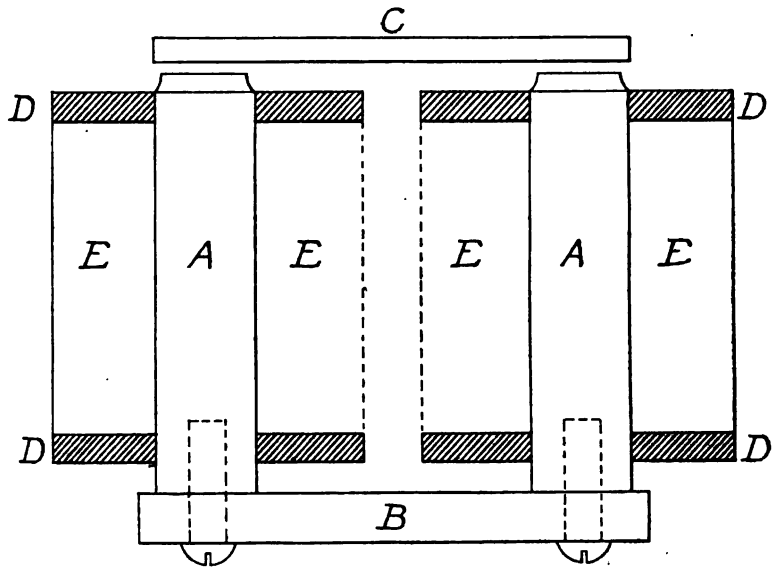


FIG. 22. Telegraphic Electromagnet.

1. The core proper, which is cylindrical in form and is the part around which the wire is coiled. It is made in two parts, *A A*, usually termed the legs or branches of the magnet.

2. A rectangular bar, *B*, which serves to unite the two parts of the core (which are secured to it by screws), and is termed the yoke.

3. A flat strip, *C*, called the armature.

The best proportions to secure the maximum magnetic effect with a given current, have been found to be those in which the four parts are of equal length; the yoke being of somewhat greater cross-section than the cores, and the armature of equal cross-section, but broader and thinner than the yoke. The results of investigation have also shown that the outer diameter of the coils or helices ought to be three times that of the cylindrical cores, and that the length of each coil or helix should be equal to its diameter. But inasmuch as quickness of movement is one of the most important considerations in telegraphic apparatus, experience has demonstrated that these proportions may be somewhat modified with practical advantage.

A series of experiments* has shown that the average period of time for a well-proportioned telegraph magnet to release its armature varies from 0.003 of a second, with maximum tension of spring, to 0.033 with minimum tension. The best working adjustment would be midway between these, that is to say about 0.015 of a second.

Data Relating to Sounders.—On lines of comparatively short length, the sounders would be placed directly in the main line according to the system of working as shown in Figs. 6, 7 and 8. They are occasionally connected in this manner on lines up to 40 or 50 miles in length. Ordinarily, however, the sounder is operated by a *local battery*, consisting of one or two gravity cells in which case its electromagnet is wound with fewer number of turns and is of lower resistance. As all sounders, whether local or main line, are made so that the armature and lever are practically of the same size and mass it is evident that by aid of the spring tension they can be adjusted till all require the same power in order to attract the armature. The standard power to operate a sounder is one fourth of a watt, which figure determines the current taken according to the resistance of its winding. The data relating to local and main line sounders of standard makes will approximate very closely the values here given:

Kind of sounder.	Local.	Main line.
Resistance in ohms,	4	20
Gauge of wire, B. and S.,	24	25
Layers per core,	10	14
Turns per layer,	45	65
Total turns,	900	1820
Ampere turns	225	225
Current in milliamperes,	250	125
Energy in watts,	0.25	0.25

Adjustments of the Sounder.—These are three in number and should be perfected in the following order:

1. Set the trunnion-screws, upon which the lever turns, as tightly as possible without in the least binding the axis. This can be determined by lifting and letting fall the lever, having first previously slackened the spring *H*, Fig. 18. It should drop freely when released.

* G. W. Dean, Coast Survey Report, 1864, p. 211.

2. Having loosened the stop *D* until the armature *A* rests upon the poles of the electromagnet, lay a piece of paper between the poles of the magnet and the armature, and close the circuit through the magnet, so that the attraction exerted upon the armature will clamp the paper. Now adjust the screw stop *D* until the armature is raised just enough to permit the paper to be drawn out without friction.

3. Adjust the stroke by means of the screw *F* and strain the retracting spring *H* until the character of the sounds produced by the up and down strokes of the lever is satisfactory.

The Relay.—When the line is of considerable length and of corresponding resistance or its insulation is defective, as is usually the case in practice, the main line current may be too feeble or too variable to satisfactorily operate the receiving instrument. Increasing the voltage of the generators so as to obtain greater line current would also increase the leakage. This might render the line inoperative as the leakage currents would now be sufficient to continually energize the sounders or at least materially interfere with the signals. At best on long lines it would require excessive

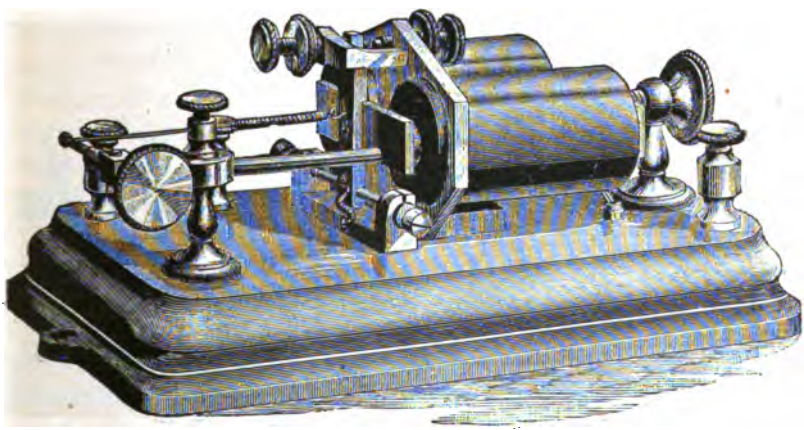


FIG. 23. Relay.

generator output to have the receivers require one-fourth of a watt each. Accordingly use is made of an intermediate receiving instrument called the relay, which is included in the main circuit in place of the sounder and is a much more sensitive instrument operating with a smaller current and requiring less energy. Its armature lever has only to perform the function of opening and closing the

circuit of a local battery at the receiving station, by which means the sounder can be made to produce any required volume of sound. The relay consists of an electromagnet, having its armature delicately poised, so as to be free and capable of being acted upon by minimum magnetic attraction. Fig. 23 represents a design which is largely used, while Fig. 24 is an elevation of the same, showing the working parts. The electromagnet *M* has its soft iron cores, usually 2 inches long and $\frac{11}{32}$ inches in diameter, screwed into a yoke *Y*, 2 inches long and $\frac{1}{4}$ inch in thickness. The standard resistance of the coils is 150 ohms and the average number of turns of No. 30 wire is 8,500. Although these figures may vary, yet the ampere turns will always remain approximately 200 to 225, the current being from 25 to 40 milliamperes. The standard amount of energy required is only one-tenth of a watt. The front ends of the magnet are supported in a vertical metallic frame *F*, the foot of which is firmly secured to a hardwood base by screws from beneath. Two circular openings are formed in this frame large enough to permit the coils to pass freely through without being fastened in any way. The yoke end of the magnet is

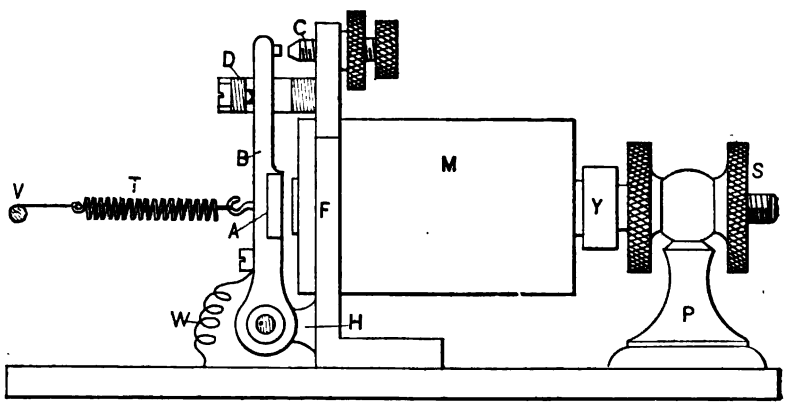


FIG. 24. Elevation of Relay.

supported at *S* by a right and left screw, or a straight screw with two check-nuts passing through a brass pillar fixed upon the base. This device is capable of imparting to the electromagnet *M* a limited horizontal advance or retrograde movement. The armature *A* in front of the poles is fixed transversely to the upright lever *B*, the lower end of which is mounted upon a steel arbor turning between two adjustable set screws, mounted upon standards *H* projecting

from the lower part of the frame *F*. The armature-lever and armature are permitted a limited movement to-and-fro upon the axis, responsive in one direction to the attraction of the electromagnet, and in the other the retractile force of the spiral spring *T*. This motion is limited in one direction by the adjustable screw-stop *C*, and in the other by a fixed stop of non-conducting material placed within the slotted projection *D*, through which the lever *B* passes freely, not touching anything but the stops. The spring *T* is attached at one end to the lever *B* by a hook, and at the other end to a thread which winds upon a spindle *V* provided with a milled head. (See Fig. 23.) This spindle is supported in a socket upon the end of a horizontal brass rod, which slides through a pillar and may be fastened in any required position by a check-screw. The object of this device is to enable the tension of the spring *T* to be adjusted through a somewhat wide range, the necessity for which will be hereinafter explained.

The electrical connections of the relay are as follows: Upon the base are four binding screws for the attachment of wires. Only three of these are visible in Fig. 23, the others being concealed by the electromagnet *M*. The insulated copper wires projecting from the helices of the electromagnet pass down through the wooden base, underneath which they are connected to the two right hand binding-posts, so that current, entering at one binding-post, after traversing both helices of the electromagnet, returns to the other and passes on. It has been explained that the function of the relay is simply to break and close the independent local circuit in which the sounder is included, whenever the main circuit is broken and closed, or in other words, to repeat the signals of the main circuit into the local circuit. To this end the armature-lever *A* is carefully insulated from the frame *F* by a non-conducting bushing interposed between the lever and the axis upon which it turns. A wire leads underneath the base from one of the left hand binding-posts to the support of the armature. Another thin copper wire *W*, coiled into a spiral, connects the armature lever with its support, being attached to the former by a small screw seen in the figure just above the axis. When the armature is attracted by the electromagnet, a platinum contact-point near the top of the lever *B* (Fig. 24) is brought in contact with a corresponding platinum point which forms the tip of the adjustable screw-stop *C*. The stop *C* is in electrical connection with the brass frame *F*, and this is in turn

connected with the extreme left hand terminal binding-post by a wire under the base. Hence it necessarily follows that whenever the two platinum points are brought in contact by the advance movement of the armature-lever in response to the attraction of the electromagnet, a connection will be formed between the two terminals completing the local circuit through the sounder.

Adjustments of the Relay.—The adjustments of the relay are three in number:—

1. The stroke, or extent of the to-and-fro movement of the armature.

2. The tension of the retracting spring.

3. The distance between the armature and the poles of the magnet.

The first-mentioned adjustment is effected by the front screw-stop *C*, which is movable, the rear stop being fixed. The maximum separation between the platinum contacts ought never to exceed $\frac{1}{32}$ of an inch, and in case the actuating current is weak, it should be made as much less than this as possible. Under ordinary conditions this adjustment, once properly made, seldom requires alteration. The second adjustment particularly requires judgment and skill on the part of the operator. When the attraction of the electromagnet is very strong, as is usually the case in wet weather, the armature will not fall off promptly, and hence the tension of the spring must be increased by turning the milled head, thus winding the thread and straining the spring. The spring *T* must never be wound around the spindle *V*. When the thread has all been taken up, the spindle must be removed to a greater distance from the armature, by loosening the check-screw and sliding the rod upon which it is mounted through the post to a sufficient distance and then clamping it again. In extreme cases the tension cannot be sufficiently increased by this means, and it then becomes necessary to resort to the third adjustment, which consists in withdrawing the magnet by the screws, so as to increase the distance between the poles of the electro-magnet and the armature. This increases the air gap in the magnetic circuit, thereby decreasing the flux and the attractive force exerted on the armature.

Needle Instrument.—The first successful telegraphs operated in Europe were those of Cooke and Wheatstone, originally employing five needles and six wires. According to this plan two converging needles were made to point to letters upon a dial; that is

to say, two out of the five needles were deflected for a given signal and the letter on the dial at the intersection of their axes was the one to be read. This was almost immediately superseded by single needle apparatus, the modern form of which is shown in Fig. 25. In the center of the face is suspended the index or pointer, which

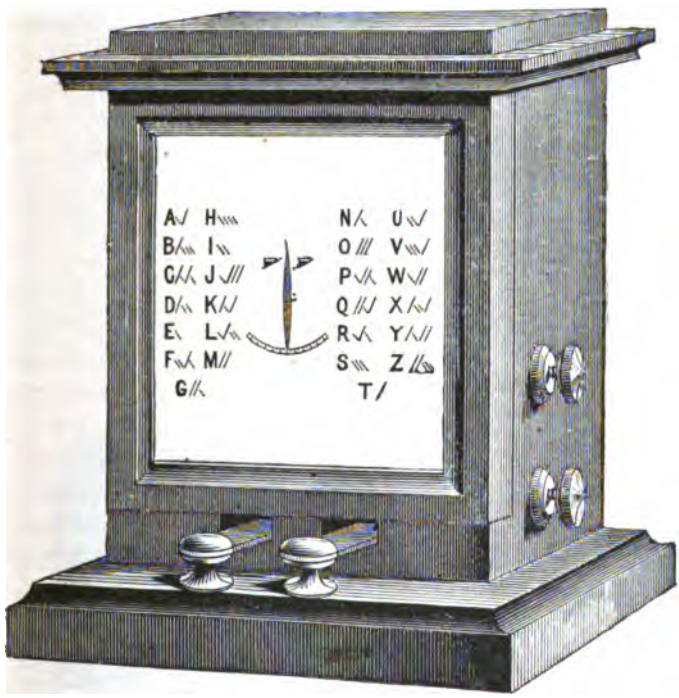


FIG. 25. Single Needle Instrument.

can deflect only a short distance to the right or left of its zero on account of its stops. The interior of the apparatus consists of two coils, of fine silk-covered copper wire, in the middle of which is suspended a magnetic needle having at the end of its axis the pointer seen on the outside of the instrument. It is essentially, therefore, a vertical galvanometer and the needle is deflected according to the direction of the current. In order to accomplish this reversal of the current, there is employed a double or tapper key, the two knobs of which protrude through the front of the instrument near the base. Combining the receiver and the transmitter, thus, into one instrament, places the apparatus in a very compact form.

Galvanometer and Siphon Recorder.—In submarine cable telegraphy the first receiver was the Thomson reflecting galvanometer which, although generally thought of in connection with electrical measurements, was invented for this purpose by Lord Kelvin. The spot of light reflected from the mirror is thrown on a screen in a darkened room. The dot and dash are distinguished from each other, not by the duration of the signal, but by the direction of the deflection of the spot of light on the screen. In the reception of signals by this instrument, two clerks are required. One to call off the words as received, the other to write them down. Also, there is no automatic record of the message made. These two disadvantages are overcome by Lord Kelvin's siphon recorder in which a fine glass siphon conducts the ink from a reservoir to a strip of paper, drawn past the point of the tube with a uniform motion. The point moves to the right or to the left depending upon the direction of the current and thus the signals are drawn on the paper in the form of curves. The apparatus, shown in Fig. 26,

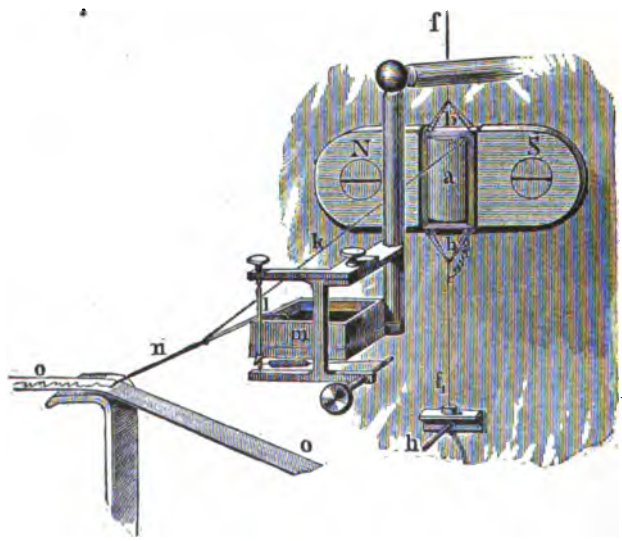


FIG. 26. Siphon Recorder.

consists of a very light rectanguler coil, bb, of exceedingly fine insulated wire, suspended between the poles of a large and powerful magnet NS. Within the coil is a stationary soft-iron core, a, which is powerfully magnetized by induction from the poles NS. The coil bb swings upon a vertical axis, consisting of a fine wire ff. the tension of which is adjustable at h. The received current

passes through the suspended coil, the suspension wire ff, serving as the conductor; the coil is impelled across the magnetic field in one direction or the other according to the direction of the current passing through it. The magnetic field in this arrangement is very intense and very uniform, which makes the apparatus sensitive to the weakest currents. The siphon, n, consists of a fine glass tube turning upon a vertical axis l; the shorter end is immersed in the ink reservoir, m, and the longer end rests upon the paper strip, oo. The siphon, n, is pulled backward and forward in one direction by the thread k, which is attached to the swinging coil bb, and in the other by means of a retracting spring attached to an arm on the axis l and controlled by an adjusting spindle. The paper is caused to move at a uniform rate by means of gearing driven by a small electric motor.

In working very long cables the action of the current upon the swinging coil is very feeble, and the friction of the siphon against the paper strip, if allowed to come in actual contact with it, would interfere with the freedom of its movements. In such cases the point of the siphon does not actually touch the paper; the ink and the paper are oppositely electrified by means of a small electrostatic machine or mouse-mill driven by the same electric motor that moves the paper. The electrical attraction causes the ink to be ejected from the siphon upon the paper in a succession of fine dots.

The operation of the Thomson siphon recorder is sometimes delayed by the failure of the ink to flow. This is generally due to an accumulation of moisture on the mouse-mill or ink-well supports, which permits the charge to escape without passing through the siphon. Cuttriss, who has greatly modified the siphon recorder in form and appearance, overcomes this difficulty by entirely dispensing with the mouse-mill and obtains the same results as follows: The siphon carries a small iron tip. The moving paper is drawn across the pole piece of an electromagnet energized by means of a vibrating rod making contact in synchronism with the natural period of the siphon. The synchronous attractions, exerted on the iron tip, cause the siphon to vibrate and record a series of dots on the paper exactly similar to those when the mouse-mill is employed.

Various Receivers.—Chemical telegraph systems, as far as recording the message is concerned, employ practically the same instruments, differing perhaps only in the solution which is used to

dampen the tape or strip of paper. A cylinder, or wheel with a smooth circumference, composed of some metal not attacked by the chemicals used, forms part of the circuit. One or more metal pens form another part of the circuit. Between the cylinder and the pens is drawn the chemically prepared paper, still moist. The current in its passage through the dampened tape decomposes the chemicals of the mixture, leaving dots and dashes on it as a result. If the solution or mixture employed be one containing iodide of potassium and starch, the current on passing will liberate the iodine, which combining with the elements of the starch will produce a blue mark on the paper. A better solution, making a more permanent record and one in which the current sets free an acid that attacks the iron or steel pen, thereby forming a combination which appears as a blue-black mark is one containing prussiate of potash and ammonic nitrate.

Dial telegraphs employ a receiver in which a needle or pointer advances over a dial by a step-by-step movement in one direction only. An electromagnet, by the alternate to-and-fro motions of its armature, imparts this motion to a peculiarly shaped toothed wheel since it receives over the line the proper number of successive impulses required to move the needle from any letter on the dial to which it may be pointing, to the next it is desired to send.

In printing telegraphs the type wheels are also moved by a step-by-step device like the pointers just described. When the proper letter or numeral is reached the printing wheel is stopped and a strip of paper is pressed against its surface. The printing wheel is kept covered with ink by means of an inked roller.

The receiver of the Wheatstone automatic system may be said to be a Morse ink-writing register modified so as to produce an exceedingly sensitive instrument. The moving paper passes near an ink-wheel delicately supported on a long, thin shaft. When a mark is produced the ink-wheel is moved till the ink touches the paper. The wheel itself, however, does not come in contact with it, and thus friction is avoided. This motion is produced by two soft iron tongues or armatures at the poles of a permanent magnet. The armatures thus polarized are attracted or repelled by the poles of a sensitive relay depending upon the direction of the current from the line.

The author wishes to acknowledge the courtesy of Messrs. D. Van Nostrand Co., in loaning him Figs. 18 and 24, being taken from Pope's Modern Practice of the Electric Telegraph.

THE OPTICAL BEHAVIOR OF QUARTZ UNDER STRESS.

By FERDINAND G. WIECHMANN.

The fact that quartz crystals cut perpendicular to their principal axis possess the property of rotating polarized light was first announced by Arago in 1811.

A few years later it was observed that the optical value which quartz-plates exhibit under normal conditions, is altered when the quartz is placed under stress.*

In view of the fact that quartz in the form of plates, lenses, prisms and wedges plays so important a rôle in various optical instruments, it seems strange that but little importance has thus far been attached to the great influence which an altered optical value of one or more of their component parts must exercise on results secured by means of such optical instruments.

Within the past year attention has been given to these matters, independently, by several investigators. At the Third International Congress of Applied Chemistry, as well as at the Second Session of the International Commission for Uniform Methods of Sugar Analysis, both of which were held in Vienna, Austria, in July, 1898, reference was made to these topics and their bearings on polariscope observations were considered by Herzfeld, Wiley, and the writer.

Since then the last named has given additional study to the problem and a statement of the results obtained may be of some interest. In various phases of this investigation the writer has profited by the counsel and help of Dr. J. A. Deghueé and of Mr. E. C. Brainerd, and he would here express his grateful appreciation of their valued assistance.

Quartz, as is well known, occurs in two modifications, right-handed (dextro-rotatory) and left-handed (levo-rotatory). A plate of dextro-quartz, for so it shall be hereafter designated for the sake of brevity, cut perpendicular to its axis, will rotate a ray of plane-polarized light to the right; a plate of levo-quartz will rotate it to the left. Both of these modifications have been included in this

* É. Verdet, Leçons d'Optique Physique, Paris, 1870. This work contains a valuable bibliography of the subjects it discusses.

examination into the optical behavior of this mineral under stress.

To guard against any possible misconception, Rankin's definition of the term stress is here inserted.

"Stress, a force, or combination of forces, which produces a strain; force exerted in any direction or manner between contiguous bodies, or parts of bodies, and taking specific names according to its direction, or mode of action, as *thrust* or *pressure*, *pull* or *tension*, *shear* or *tangential stress*."

No account will here be taken of the *temporary* stress induced for instance, in the warming of quartz wedges, caused by the elevation of temperature proceeding gradually from the outer rims to the interior portions of the material, for Professor Herzfeld has specifically called attention to these phenomena.*

Neither will reference be made to the well-known increase in the rotatory power of quartz when induced solely by an elevation of its temperature.

Temperature changes will concern us only inasmuch as they may bring about conditions of stress by causing expansion or contraction in the mounting of the quartz wedges, plates, etc.

The pressure and tension effects were studied principally by means of devices made for the purpose and shown in the annexed sketches.

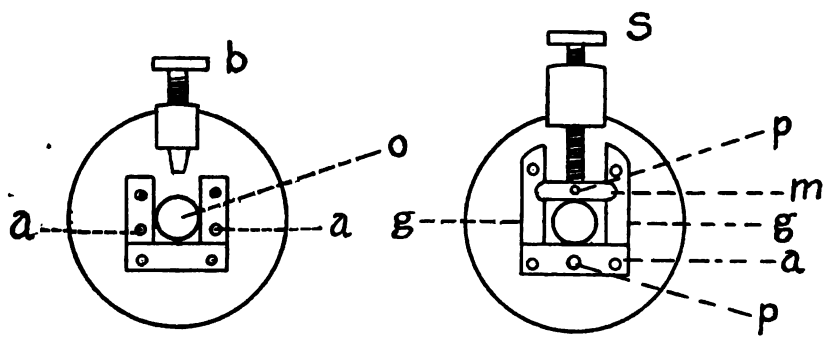


FIG. 1.

In making the pressure determinations the quartz plate was inserted between the body of the apparatus and the grooved guides *a*, *a*; pressure was applied at will by means of the screw *b*.

* Zeitschrift des Vereins der Deutschen Zucker-Industrie, 1899. Technischer Theil, pp. 1–20.

The ray of light traversed the quartz plate at *o*, a circular opening extending entirely through the body of the apparatus.

In the tension determinations the quartz plate, provided with two holes, was held in place by two pinions *p*, *p*, which projected from the stationary bar *a*, and the movable bar *m*. The latter was grooved and moved between the stationary guides *g*, *g*. Greater or less tension could be applied at will by means of the screw *s*. The light traversed the quartz plate at *o*, a circular opening extending completely through the body of the apparatus.

The measurements were made with a very sensitive and accurate double-wedge compensation polariscope recently built to order by Julius Peters, Berlin, and officially tested and certified to as correct by the Chemisches Laboratorium, Verein der Deutschen Zucker-Industrie, in Berlin. One of the special and, it is believed unique features of this instrument is the device whereby its quartz wedges are mounted without cement or wax; they are held in place by delicate plates and plate-springs and thus escape all danger of stress which might be induced by variations of temperature.

Throughout these experiments, however, the temperature of the polariscope was kept constant, *i. e.*, between 18° and 18.5° C. All readings taken were direct readings, that is to say, those taken on the dextro-quartz plates were obtained by means of the *A*-wedge of the polariscope, those secured on the levo-quartz plates were found by means of the *C*-wedge of the instrument.

The results secured in these trials were all in accord with the one set of observations which is recorded in the following table:

Stress produced by Pressure.			Stress produced by Tension.		
		Rotatory Value of Quartz plate, degrees Ventzke.			Rotatory Value of Quartz plate, degrees Ventzke.
Dextro-Quartz.	Original	+ 80.4	Dextro-Quartz.	Original	+ 97.2
	Under pressure	+ 81.2		Under tension	+ 98.3
	Under increased pressure	+ 84.2		Under increased tension	+ 99.6
Levo-Quartz.	Original	— 91.4	Levo-Quartz.	Original	— 93.2
	Under pressure	— 92.7		Under tension	— 94.0
	Under increased pressure.	— 97.0		Under increased tension	— 94.5

It should be remarked that in all of these cases, when the stress (pressure or tension) was removed the quartz plates regained their original rotatory power. In the tension experiments this original value was regained somewhat more slowly than in the pressure experiments, possibly because in the latter the stress had been distributed only from one point of pressure throughout the quartz plate, whereas in the tension tests there were two points of support from which the tension emanated.

The results obtained may be graphically thus presented:

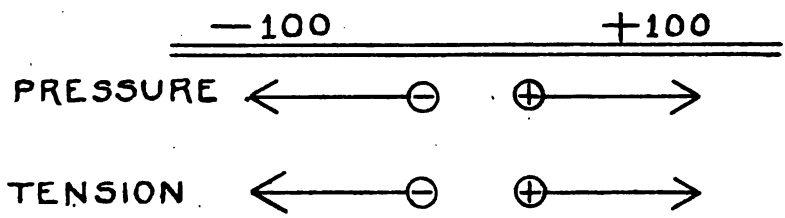


FIG. 2.

Considering "zero" as the starting point, it appears that:

Dextro-quartz under stress (pressure, tension) experiences an increase in its positive rotatory value; thus a plate having a normal value of + 90° Ventzke, would, under stress, have this value changed so as to approximate more closely to a higher value, + 100°, for instance.

Levo-quartz under stress (pressure, tension) experiences an increase in its negative rotatory value; thus, a plate having a normal value of — 90° Ventzke, would, under stress, have this value changed so as to approximate more closely to a higher value — 100°, for instance.

The above results illustrating the effect of pressure on plates of dextro-rotatory quartz are in perfect accord with results obtained in July, 1898, by Professor Dr. Herzfeld and the writer in the laboratory of the former, at Berlin. The experiments there made were conducted with a quartz plate loosely mounted, but so held that, through the tightening of screws, pressure of varying intensity could be exerted upon it.

The optical value of this plate at 20°C. was about 86° Ventzke. By gradually increasing the pressure upon it, the temperature remaining constant throughout, this plate showed an increase in rotatory power, which was carried up to over 100° Ventzke. At this

point the pressure was discontinued for fear of fracturing the plate. On releasing it from pressure, the plate quickly resumed its original rotatory value.

A case which shows that a sudden and marked change of temperature to which a mounted quartz plate is subjected, may materially and, as it seems in some instances permanently, change its optical value, is the following:

A quartz plate which has been in the possession of the writer for at least ten years and which had always shown a value of 99.9 to 100.0 when tested against chemically pure sugar, after a short immersion in water of 35°C., exhibited an optical value of 100.3. This change of value occurred more than half a year ago and the plate to this day retains its newly acquired value.

In addition to the experiments thus far mentioned and which were made with quartz plates, the effect of stress (pressure) was tried on dextro- and on levo-quartz wedges and on quartz compensating plates *in situ* in sugar polariscopes. All of these tests resulted similar to those above recorded. One polariscope having a levo-quartz wedge, and, of course, a dextro-quartz compensating plate, was so arranged that stress (pressure by means of steel screws) could be exercised at pleasure on either wedge or plate, or simultaneously on both.

A sugar solution placed in the polariscope and remaining unchanged throughout the experiment, read while there, was:

No stress on wedge No stress on plate	+ 98.8	Stress on wedge No stress on plate	+ 90.0
No stress on wedge Stress on plate	+ 105.0.		

By varying the stress on wedge and plate any and all readings could be secured at will. In every instance, on removing the stress, the polariscope again recorded the original reading of the solution, + 98.8.

To illustrate the practical bearing which the facts thus ascertained may have in scientific investigations, there shall be considered the conditions which would arise in case one or another of the quartz components of a polariscope were placed under stress. But before so doing it may be desirable to premise a few words on polariscopes and the principle which underlies their use.

The type of polariscope here selected for discussion shall be the saccharimeter, an instrument much used to ascertain the saccharine value of sugars.

This instrument is based on the principle, discovered in 1815 by Biot, and independently by Seebeck, that some liquids share with certain crystals the property of rotating the plane of polarized light.

Among others, sugar solutions possess this power. As the rotation-dispersion of quartz and of sucrose are almost identical, it is possible by the means of white light to determine the amount of sucrose in a solution (prepared under certain conditions), by compensating with quartz wedges the deflection of the plane of polarized light caused by the sucrose solution.

The first quartz-wedge compensation saccharimeter was constructed by Soleil in 1848, and his instrument may be regarded as the prototype of all saccharimeters of to-day.

The use of a polariscope of this kind is very simple. The instrument being set at zero, any optically active substance which may be introduced between the polarizer and analyzer, will disturb the optical equilibrium. To restore the same, instead of turning the analyzer, there is inserted between it and the polarizer a quartz plate, dextro-or levo-rotatory, as the case may require and of a thickness sufficient to make the algebraic sum of the rotations of the quartz and of the substance examined, equal to zero. The function of Soleil's compensating quartz wedge is practically that of a quartz plate the thickness of which can, within certain limits, be varied at will.*

The quartz wedges are as a rule mounted in metal frames and these are provided with a scale graduated according to some chosen standard.

The graduation of the polariscope scale which is in general use in the United States, is effected by ascertaining the 100 degree mark of such scale at the temperature of 17.5°C., by means of a sugar solution containing 26.048 grammes of chemically pure sucrose, weighed in air with brass weights, made up to 100 Mohr cubic centimeters at 17.5°C., and polarized at the temperature of 17.5°C., in a tube 200 mm. long.

* Landolt, Das Optische Drehungsvermögen Organischer Substanzen. II. edition 1898, p. 328 et seq.

In commercial practice, 26.048 grammes of the sugar to be examined are weighed in air by means of brass weights and thereupon dissolved in water, the solution being made up to a volume of 100 Mohr cubic centimeters, the requisite amount of clarifying reagents having been previously added. This solution is filtered, the filtrate so obtained is put into a polariscope tube 200 mm. long, and the reading of this solution is secured on a polariscope the correctness of which has been ascertained and which is in correct adjustment. The reading thus found is called the polariscopic test of the sugar and is the factor upon which the commercial valne of the sugar is based.

In scientific determinations it is customary to express the extent to which optically active substances rotate the plane of polarized light in different terms.

If the substance examined be a solid, the angle of rotation is usually referred to a layer one millimeter in thickness, for the amount of rotation produced is proportional to the thickness of the layer traversed by the light.

If the substance examined be a liquid, its power of rotating polarized light is expressed in terms of *specific rotation.* This term was introduced by Biot and is defined as: the angle of rotation $[\alpha]$ given by a length of one decimeter of a solution, which contains one gramme of active substance in the volume of one cubic centimeter.

The angle of rotation of solutions is proportional not only to the length of the column of solution traversed by the light, but varies also with the wave-length of the light ray employed; it is greatest for the violet and least for the red rays.

Usually the homogeneous yellow light of a sodium flame corresponding to the Frauenhofer line *D* is selected for the observation of specific rotatory values and some one temperature is chosen at which the observations are conducted.

Values thus obtained are expressed by means of the formula:

$$[\alpha]_D^{20^\circ} =$$

The specific rotation values thus found are constants, and of value in the identification of optically active bodies.

The relation between Ventzke scale-degrees and circular degrees is thus expressed by Landolt:*

* Op. cit., p. 337.

100° Ventzke = 34.68 circular degrees (Ray *D*) at 17.5° C.
and, 100° Ventzke = 34.69 circular degrees (Ray *D*) at 20° C.
By aid of the factors thus given it is a simple matter to translate circular degrees into degrees Ventzke, and *vice versa*.

Having thus indicated the principles and practice governing the use of saccharimeters, return shall be had to the question at issue, the manner in which stress exercised on the quartz components of saccharimeters may influence observations made thereon.

Some saccharimeters are provided with single, others with double compensation wedges of quartz. These wedges are, as before mentioned, mounted in metal frames which bear the scale.

If the wedge be made of dextro-quartz the 100° mark of the scale is placed over the thin end of the wedge; if made of levo-quartz the 100° mark is placed over the thick end of the wedge. This is shown in the sketches subjoined.

A dextro-rotatory substance retaining a constant optical value would *apparently* have different readings when examined with a saccharimeter, the wedges of which were put under stress after they were mounted and had been provided with a scale.

DEXTRO-QUARTZ WEDGE.

Under pressure.—Optical value increases. Less thickness of

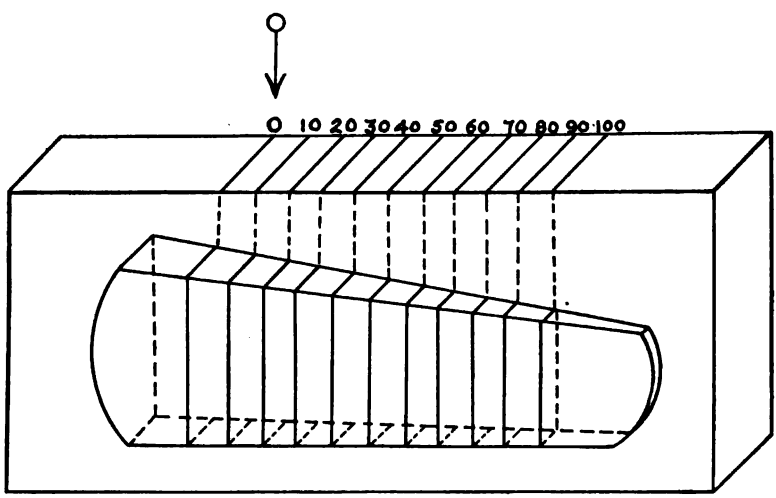


FIG. 2.

wedge will therefore be required to compensate for a given dextro-rotatory substance and a *lower* scale reading will result.

Under tension.—Same as above.

LEVO-QUARTZ WEDGE.

Under pressure.—Optical value increases. Less thickness of wedge will therefore be required to compensate for a given dextro-rotatory substance and a *lower* scale reading will be obtained.

Under tension.—Same as above.

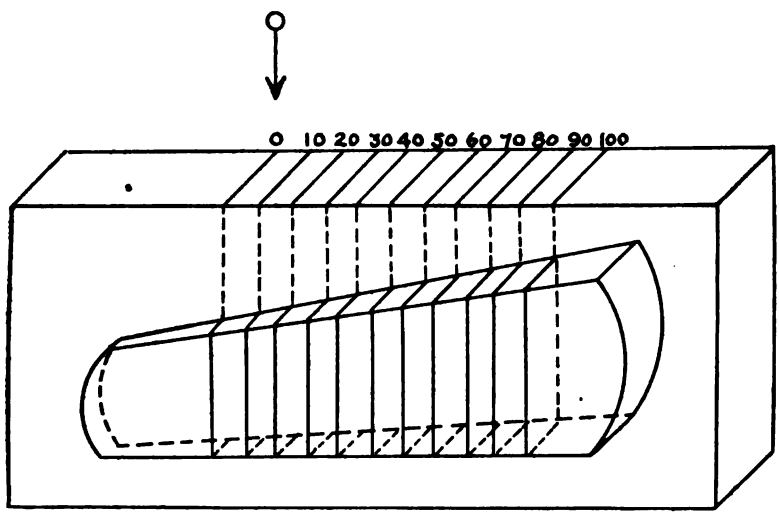


FIG. 3.

It will thus be seen that under these circumstances stress (pressure, tension), exercised on either dextro- or levo-quartz wedges, will result in assigning a lower rotatory value to any given dextro-rotatory substance examined, a sugar solution for instance, than it really possesses.

If, on the contrary, stress be exercised not on the quartz wedges but on their stationary quartz compensating plates, the results which must follow can be easily traced.

What, however, would result if a quartz wedge, one of levo-quartz for instance, were mounted *while under tension?*

In that case, the scale graduated at 17.5° C. would have its 100° mark placed over a certain portion of the quartz wedge which in reality possesses a *lower* rotatory value.

Carrying the temperature of the polariscope *above* 17.5° C., the tension, caused by the metal frame shrinking away from the quartz for the mounting, wax or cement, adheres to both frame and wedge—the tension will increase the rotatory value of the

quartz wedge and the scale-reading obtained will, in consequence, be *lowered.*

Bringing the temperature of the polariscope *below* 17.5° C. would cause the tension under which the quartz wedge was originally mounted to relax. In consequence the wedge will assume, or at least approach, its true rotatory value, which is lower than was assumed in placing the scale, and the reading obtained will, therefore, be found *higher* than before.

A chemically pure sucrose solution, normally and properly polarizing 100° Ventzke, would, if examined in a polariscope having the defect described, show: At temperatures *above* 17.5° C., polarizations *under* 100%; at temperatures *below* 17.5° C., polarizations *above* 100%.

As to the possibility, not to say the probability of a quartz wedge too snugly mounted being under tension, it should be borne in mind that, the metal frame, the cement (wax) and the quartz wedge must at least be warm, while the setting is accomplished.

The metal frame, having the highest conductivity for heat, will of course cool first and this, while the cement (wax) and the quartz wedge are still warm.

The cement (wax) will cool next and this while some heat is still retained by the quartz wedge, which is, in consequence, somewhat expanded. When the wedge cools, it will, of course, contract and as the cement or wax is already hardened, the quartz wedge will thus be held under tension.

This specific case, *i. e.*, that of levo-quartz wedge mounted while under tension, has here been purposely selected for illustration on account of the intimate bearing it may have on an interesting question which at present is attracting considerable interest in certain scientific circles.

The question at issue is this: Is the specific rotation of sucrose in solutions of a known concentration, constant or not constant, at various temperatures?

While many observers have, in agreement with the writer, thoroughly satisfied themselves that the value in question is virtually a constant, at least within the range of temperature in which observations have been made (vide von Lippman, Die Chemie der Zuckerarten, II. Edition, *1895*, p. 672), the contrary has been maintained by some investigators.

Thus Harvey W. Wiley, Chief Chemist of the United States De-

partment of Agriculture, at the Third International Congress of Applied Chemistry, held in Vienna in July and August, 1898, presented a paper on "The Influence of Temperature on the Specific Rotation of Sucrose."

In an abstract of this article, published by Dr. Wiley in *The Journal of the American Chemical Society*, Vol. 21, *1899*, pp. 84, 85, he states: "The methods of research employed were described in detail, and all the disturbing forces discussed and the degree of disturbance determined for each. It was shown that on using a compensating quartz wedge to determine the degree of the rotation the temperature influenced the results obtained in the following ways:

1. It causes a change in the rotatory power of the quartz wedge, this power increasing with a rising temperature. From this it follows that a less thickness of the wedge is necessary to produce a given compensation at a high temperature.

2. The volume of the flask increases with a rising temperature, and hence the volume of the solution is greater as the temperature rises.

3. The weight of water in a given volume decreases as the temperature rises, and hence arise differences in the concentration of the solution.

4. The length of the observation tube increases with a rising temperature.

5. The degree of concentration of the solution affects its specific rotatory power.

6. Any variations in specific rotatory power, which are observed after introducing the correction for the disturbances above noted, must be due to direct effect of the change of temperature on the specific rotatory power.

7. Making the corrections noted, it was found that the specific rotatory power of pure sucrose at different temperatures is as follows:

$$\text{At } 4^\circ \; aD = 66.653^\circ.$$
$$\text{At } 17.5^\circ \; aD = 66.547^\circ.$$
$$\text{At } 40^\circ \; a \quad 66.340^\circ."$$

From these statements it appears that Dr. Wiley found that the specific rotatory power of a sucrose solution which had a given value (66.547 circular degrees) at 17.5° C. had an *increased* value

when determined at temperatures *below* 17.5° C. and a *decreased* value when examined at temperatures *above* 17.5° C.

From these data Dr. Wiley drew the conclusion that the specific rotatory power of sucrose decreases with increasing temperature.

In view of the behavior of quartz under stress as herein recorded, it is evident, however, that an explanation of Dr. Wiley's results may be possible without assigning to sucrose a specific rotation variable with the temperature. The optical behavior of a levo-quartz wedge mounted under tension would account for all of the phenomena observed by Dr. Wiley, for this would apparently cause the sucrose solution to exhibit variations in its specific rotatory value which, in truth, it had never experienced.

Prof. Dr. Alexander Herzfeld, of Berlin, the great German authority on sugar chemistry, also holds the opinion that stress on the quartz wedge of Dr. Wiley's polariscope may have led to the conclusion this investigator reached with respect to the variability of the specific rotatory power of sucrose.

In his official report as president of the Second Session of The International Commission for Uniform Methods of Sugar Analysis, Vienna, July, 1898, Prof. Herzfeld, referring to some observations made jointly by him and the writer of this article, on the influence of pressure on quartz plates, says: "These pressures, to which thus far no attention has been paid, will also make their influence felt in the quartz wedges of the polariscopes, which, as is known, are also cemented in place, and which, therefore, must be submitted to varying pressure on experiencing elevations of temperature. This, too, was probably the cause of the errors disclosed by Wiley."

Furthermore, in an article, "On the Influence of Temperature on the Readings of Saccharimeters" (Zeitschrift des Vereins der Deutschen Zucker-Industrie, 1899, Technischer Theil, pp. 1–20) Professor Herzfeld writes:

"The foregoing experiments clearly demonstrate that in the half-shade polariscopes examined, variations in polarizations, caused by changes in temperature are not to be feared, *because the instruments themselves become faulty.*

However, it cannot be claimed that such faulty instruments do not exist. The experiments of Wiley, the results of which are the reverse of my own, may, indeed, have been burdened with errors similar to those of my own first experiment, but possibly, Professor Wiley may have happened to have had under his hands instru-

ments, the quartz wedges of which, were, on elevation of temperature, exposed to stress in consequence of being too snugly cemented in place."

It would thus appear that in this interesting problem, the constancy of the specific rotation of sucrose at various temperatures, as well as in similar quantitative determinations, due regard should be had to possible disturbances caused by alterations in the optical behavior of quartz under stress.

IN MEMORIAM.

WILLIAM ALLEN SMITH.

William Allen Smith was born in Amherst, Massachusetts, August 16, 1848; became, as a child, a resident of New York City; and died here suddenly on March 24th of the present year. Both on his father's side and on that of his mother he came of English stock, long settled in New England. On his mother's side there was also a strain of French Huguenot blood. On both sides he was descended from long lines of college-bred ancestors—clergymen, professors, college presidents, judges and statesmen, men of affairs and leaders of thought and action in the communities in which they lived.

Mr. Smith left the Free Academy—since better known as the College of the City of New York—in 1865, in order to enter the then newly established School of Mines. He graduated from this institution with the degree of Engineer of Mines in 1868. Immediately after graduation he accompanied his parents to Europe, intending to continue his studies at the University of Berlin. He spent the summer in travelling through Europe, visiting mines and metallurgical establishments. In the autumn Minister Bancroft offered him the position of private secretary, which he accepted as a temporary arrangement, with the intention of resuming later his studies in the University. He proved, however, so acceptable to Mr. Bancroft, and his work, which consisted largely in historical investigation, was so interesting to him, that he retained his posi-

tion until October, 1872, when he resigned to return to this country. Shortly after his return a position was offered him by Cooper, Hewitt & Co., in the works of the New Jersey Steel and Iron Company at Trenton, where he remained until June, 1877. In October of the same year he concluded a three years' contract with Phelps, Dodge & Co., with whom he remained for nearly five years, spending three years in Ansonia, Connecticut, at their brass works, and the remainder of the time as manager of the Weldon Mining Company, in the vicinity of Dover, New Jersey. In 1883 he was appointed secretary of the then recently organized Iron and Metal Exchange, which office he held during the succeeding year, resigning it to become treasurer of the Harvey Screw and Bolt Company. This office he held for more than two years, until the Company was consolidated with the American Screw Company. For several years he had an office as consulting engineer, being employed in that capacity by several companies. In the academic year of 1891–92, during the absence of the writer in Europe, he filled the position of Lecturer on Mining and Ore Dressing in the School of Mines, and also took charge of the Summer School of Practical Mining. His work, both as lecturer and instructor, was singularly successful, and the degree in which he won the regard and affection of his students was evidenced by their presentation of a loving cup on the termination of his temporary connection with the School. In the spring of 1893 he was appointed treasurer of the Harvey Steel Company, which position he held at the time of his death, managing the affairs of that important company with great ability and success.

In December, 1874, he married Zilpha Cutler, of Portland, Maine, who is living in New York with their eldest son and one daughter. A second son, William Allen Smith, Jr., was graduated from the School of Mines in June, 1898, with the degree of Engineer of Mines, and is now in the employ of the Kansas City Smelting and Refining Company.

To the keen intelligence and scholarly tastes which he inherited from his New England ancestors was added a lively interest in the practical side of life, which led him early to turn his studies to the field of applied rather than pure science, and later to the economic and business side of his profession rather than to scientific and engineering details. He was a man of generous sympathy and warm heart, always ready to devote time and energy to the public good

or to aid friend or acquaintance. This spirit of helpfulness led him always to take a lively interest in the affairs of the community in which he lived and forced him to take a prominent part in such affairs wherever he saw that he could do beneficial work or help to accomplish some important end.

His work as an officer and as President of the School of Mines Alumni, and as its representative on the University Alumni Council, was only one manifestation of the public spirit that dominated him. Those who have worked with him know how heartily he entered into the affairs of the alumni and how valuable service he has rendered to this Council.

William Allen Smith had in high degree that sense of humor which is said to be our national heritage; but its subtlety, its delicacy and refinement were anything but common. He had also the American disposition to take, wherever it was possible, the humorous view of things; and this helped to make life easier to him as well as pleasant to his friends and associates. But he drew the line where Americans do not always draw it and was unable to see anything humorous in meanness or wrong. He was of what Holmes has called the Brahmin caste of New England, and under the easy genialty of the modern American he possessed, with unweakened fibre, the sturdy qualities of his lineage—the Huguenot gentleman's sense of honor and the English Puritan's sense of right.

H. S. M.

ABSTRACTS.

METALLURGY FOR 1898.

By Joseph Struthers, Ph.D.

The following list of note references is composed of the more important articles on general metallurgical practice which have appeared in the scientific periodicals during the year 1898:

Abbreviations Employed.

Amer. = American.	Mach. = Machinist.
Aust. = Australian.	Mag. = Magazine.
Can. = Canadian.	Manuf. = Manufacturer.
Chem. = Chemical.	Mech. = Mechanical.
Col. = Colliery.	Min. = Mining.
Eng. = Engineering.	Rev. = Review.
Guard. = Guardian.	Sci. = Scientific.
Inst. = Institute.	Soc. = Society.
Journ. = Journal.	Trans. = Transactions.

Refractory Materials.

The Manufacture of Fire-clay Goods from the Under-clays of Thin Coal Seams. Philip Kirkup. Paper read at meeting of Fed. Inst. of Min. Engs., at Newcastle-on-Tyne. *Col. Guard.*, March 5, 1898.

The Bauxite Industry. W. M. Brewer. Report of this industry in Alabama and Georgia. *Eng. and Min. Jour.*, April 2, 1898.

Fire Clays. T. C. Hopkins. General descriptive with illustrations. *Mines and Minerals*, Sept., 1898.

A Modification of Bischof's Method for Determining the Fusibility of Clays, as Applied to Non-Refractory Clays, and the Resistance of Fire-Clays to Fluxes. H. O. Hofman. Explains the direct and indirect methods, and states the experimental tests made to verify the method. *Amer. Inst. Min. Engs.*, Oct., 1898.

Does the Size of Particles Have any Influence in Determining the Resistance of Fire Clays to Heat and to Fluxes? H. O. Hofman and B. Stoughton. Report of a series of tests. *Amer. Inst. Min. Engs.*, Oct., 1898.

Clay Resources of Missouri. H. A. Wheeler. *Eng. and Min. Jour.*, Oct. 8, 1898.

Clays of Louisiana. W. W. Clendennin. Report. *Eng. and Min. Jour.*, Oct. 15, 1898.

Fuel.

Modern Types of Gas Producers. Part first discusses recently processes for making gas and different types of producers. *Iron and Coal Trades Review*, Jan. 21, 1898.

An Automatic Feed-Device for Gas Producers. C. W. Bildt. Illustrated description. *Trans. Amer. Inst. Min. Engs*, Feb., 1898.

Alabama Coal in By-Product Ovens. William B. Phillips. Testing of this coal, recovery of by-products and the production of coke suitable for use in the blast furnace. *Amer. Manuf. and Iron World*, April 1, 1898.

The Chemistry of the Coals of the Clyde Basin. W. Carrick Anderson. Summary of paper read before the Philosophical Society of Glasgow, written in competition for the Graham Gold Medal. Investigations of difference in character and reaction between non-coking and true coking varieties. *Col. Guard.*, April 22, 1898.

The Chemical Analysis and Testing of Fuel. L. Campredon. From *Annales de Chimie Analyt. Col. Guard.*, April 29, 1898.

By-Product Coke-Making in Germany. From a British Consular Report by T. R. Mulvany. *Col. Guard.*, April 29, 1898.

Coke Ovens and By-Products in Germany. Abstract from a foreign office report by Kurt Seebohm. *Iron and Coal Trades Review*, April 29, 1898.

The Breaking and Classifying of Coke. M. Hoyer. Translated from *Le Gaz.* Read before the Société Technique Belge de l'Industrie du Gaz, as a continuation of a similar paper read in 1896. *Progressive Age*, May 2, 1898.

On Coking in By-Product Ovens. John H. Darby. Read before the Iron and Steel Institute. Semet-Solvay practice shows that well-made retort coke is economical in the blast furnace, and that some fuels that will not coke satisfactorily in the beehive ovens, will produce a marketable coke in the retort oven. *Industries and Iron*, May 13, 1898, and *Eng.*, July 1, 1898.

Modern Systems of Coking. (Die Heutigen Koksöfensysteme.) A discussion of coking with ovens for saving the by-products; with especial reference to the Neinhaus oven. *Glückauf*, July 9, 1898.

The Calorific Value and Moisture of Lignite. (Heizwert und Wassergehalt der Braunkohlen.) L. C. Wolff. A study of German lignites or "brown coals," with computations of the calorific values. *Zeitschr. der Ver. Deutscher Ingen.*, July 9, 1898.

The Ljungberg Continuous Charcoal Kiln. E. J. Ljungberg. Describes the continuous kiln and its operation. *Iron Age*, July 28, 1898.

The Recovery of By-Products in Coke-Making. (Anlagen zur Gewinnung der Nebenproducte im Kokereibetrieb.) Rudolf Terhaerst. Notes on the construction of the ovens and the condensing apparatus for the recovery of tar, ammonia and benzol. *Stahl und Eisen*, Aug. 15, 1898, and *Iron and Coal Trades Reviews*, Sept. 23, 1898.

The Use and Manufacture of Coke in the Iron and Steel Industries. Discusses the economic value of coke and the method of its preparation and describes blast furnace fuel, and the charges, cost and economy. *Col. Guard.*, Aug. 26, 1898.

Development of By-Product Coke-Making. From advance sheets of the report on the "Manufacture of Coke in 1897," by Edward W. Parker, of the U. S. Geological Survey. *Amer. Manuf. and Iron World*, Aug. 26, 1898.

The Otto Coke Oven and the German Coke Industry. A German compilation showing the enormous advance in by-product saving in the Ruhr district, and the Otto oven. *Iron and Coal Trades Review*, Sept. 9, 1898.

The Riche Gas Producer. A. Lombard. Translated from the French. Describes the producer and its working. *Amer. Manuf. and Iron World*, Oct. 7, 1898.

A New Process of Combustion. (Illustrated.) Paul J. Schlicht. *Journ. Frank. Inst.*, Nov., 1898.

The Calorific Power of Weathered Coals. R. S. Hale and H. J. Williams. Tabulated results of analyses with statement of conditions. *Trans. Amer. Soc. Mech. Engrs.*, Nov., 1898.

The Coking of Inferior Coals with the aid of Pressing Machines Translated from *Stahl und Eisen*. *Iron and Coal Trades Rev.*, Dec. 16, 1898.

The Coking of Lean Coals. O. Simmersbach. *Stahl und Eisen*, Dec. 1, 1898.

PROPERTIES OF PIG IRON.

Notes on the French Pig Iron Industry. (Mittheilungen über die Französische Roheisen-industrie.) A tabular review of French iron production by departments. *Stahl und Eisen*, Jan. 15, 1898.

English and American Methods in the Engineering and Iron Trades. From presidential address of Henry Webb before the Manchester (England) Association of Engs. *Eng.*, Lond., Jan. 21, 1898.

Effects of Phosphorus on the Strength and Fusibility of Iron. Thomas D. West. Read at meeting of the Pittsburg Foundrymen's Association. *Amer. Manuf. and Iron World*, Feb. 4, 1898.

The effect of Ferro-Sodium on Cast Iron. Walter J. May. *Practical Eng.*, Jan. 28, 1898.

Test Bars and Their Relation to the Strength of Castings. Herbert E. Field. *Machinery, N. Y.*, Feb., 1898.

The French Pig Iron Industry. From an article by Oscar Simmersbach in *Stahl und Eisen*. *Amer. Manuf. and Iron World*, Feb. 11, 1898.

The Location of Pig Iron Production in the United States shows that the center of pig iron production has passed to the Central West—the district of Pittsburg, Cleveland and Chicago. *Eng. and Min. Jour.*, Feb. 26, 1898.

Sandless Pig Iron. E. A. Uehling. Read before the Pittsburg Foundrymen's Assn. Showing the advantage of sandless, or machine made, pig iron. *Iron Age*, March 3, 1898.

The Cost and the Conditions of Producing Iron and Steel in Different Countries. Part first deals with the manufacture of pig iron in Great Britain. *Iron and Coal Trades Review*, April 1, 1898. Serial. First part.

Need of Greater Uniformity in Pig Iron Analyses. Thomas D. West. Read by title before the Pittsburg Foundrymen's Assn. Considers the value of chemical analyses, and factors that affect the results. *Amer. Manuf. and Iron World*, April 15, 1898.

How to Secure Uniformity in Pig Iron Analysis. Extracts from letters on paper of Thomas D. West before the Pittsburg Foundrymen's Asso-tion. *Iron Trades Review*, May 5 and May 12, 1898.

Sampling Pig Iron for Analysis. Albert Ladd Colby. A discussion of the methods of sampling pig iron. *Iron Age*, June 2, 1898.

Manganese in Cast Iron and Some Experiments Thereon. Guy R. Johnson. Read before American Foundrymen's Association. *Foundry*, Sept., 1898.

On the Action of Metalloids on Cast Iron. Guy R. Johnson. Read before the Iron and Steel Institute, Stockholm meeting. A discussion of the effect of each element on the properties of the iron and on the state of the other metalloids, with tables of tensile tests in which each element in turn is varied, the others being held constant. *Industries and Iron*, Sept. 9, 1898. Serial. First part.

The Melting Point of Cast Iron. Dr. R. Moldenke. Read before the Pittsburg Foundrymen's Association. Describes and illustrates the Le Chatelier pyrometer modified for determining melting temperatures of cast iron, giving results obtained and general observations. *Iron Age* Oct. 20, 1898, and *Iron Trades Review*, Nov. 17, 1898.

Metalloids in Castings. Malcolm McDowell. A paper read before the Engineers' Society of Western Pennsylvania. General discussion. *Iron Trades Review*, Nov. 24, 1898.

Blast Furnace Practice.

Brick Manufacture from Granulated Blast-Furnace Slag. F. W. Leurmann. Condensed translation of article on *Stahl und Eisen. Amer. Manuf. Iron and World*, Jan. 14, 1898.

The Sulphur Contents of Coke in their Relation to Blast Furnace and Cupola Practice. Oscar Simmersbach. Translated from *Stahl und Eisen. Amer. Manuf. and Iron World*, Jan. 28, 1898.

Destruction of Blast-Furnace Lining by Carbon. F. W. Luermann. Translated from *Stahl und Eisen. Amer. Manuf. and Iron World*, March 11, 1898.

The Recovery of By-Products of the Blast Furnace. A Humboldt Sexton. A review of the various methods employed for the recovery of pitch, oil, paraffin and sulphate of ammonia in the west of Scotland. *Engineering Magazine*, March, 1898.

The Heat Balance of the Blast Furnace. (L'Equilibre Calorifique du Haut-Fourneau.) G. Rocour. A discussion of the thermal interchanges which take place in the smelting or iron, with examples of the method of computing the thermal efficiency of the blast furnace. (Ill.) *Revue Universelle des Mines*, April, 1898.

On the Relative Merits of Limestone and Lime in Blast Furnace Practice. Charles Cochrane. Read before the Iron and Steel Inst., England. *Industries and Iron*, May 13, 1898.

Slag Bricks in Germany. Bricks made from granulated slag, and their superiority to bricks made of fluid slag. *Consular Reports*, No. 144, June 18, 1898.

Management of Blast Furnaces—Transition from "Rule of Thumb"

to Application of Scientific Methods. E. S. Cook. Discusses furnaces, fluxing, fuel, ores, limestone, pig iron, furnace management, modern construction, etc. *Sch. of Mines Quar.*, April, 1898, *Iron Trades Review*, July 21, 1898, and *Can. Min. Rev.*, Aug., 1898.

Note on the Forms Assumed by the Charge in the Blast Furnace, as Affected by Various Methods of Filling. Frank Firmstone. *Trans. Amer. Inst. Min. Engs.*, Aug., 1898.

The Manufacture of Slag Cement. E. May in *Stahl und Eisen*. *Iron Age*, Sept. 1, 1898.

The Heating of the Blast for Blast Furnaces. (Die Winderwärmung an den Hochöfen.) F. Braune. A discussion of the advantages of heating the blast, with illustrations of the more recent hot-blast stoves. *Zeitschr. d. Ver. Deutscher Ing.*, Sept. 10, 1898.

The Extraction of Iron from Its Ores in the Blast Furnace. James Tomkins. From a paper read before the Derbyshire Metallurgical and Engineering Ass'n. *Col. Guard*, Sept. 30, 1898.

Iron Carbonyl in the Blast Furnace. F. P. Venable. Some facts with regard to the possible part played by this compound. *Amer. Manuf. and Iron World*, Oct. 28, 1898.

Review of Recent Progress in the Metallurgy of Iron. (Revue des Progrès Récents de la Metallurgie du Fer.) MM. de Billy & Marillier. The annual review of the *Société d'Encouragement*, giving a résumé of the advances made during the year. *Bulletin de la Société d'Encouragement*, Sept. 1898.

The Cost of Producing Pig Iron in Alabama. Wm. B. Phillips. Statistics. *Amer. Manuf. and Iron World*, Dec. 2, 1898.

The Costs of Pig Iron in Relation to the Ore. Walter J. May. *Mech. Eng.*, Dec. 2, 1898.

Foundry Practice.

The Avery Molding Machine. Illustrated description, apparatus and plan of molding. *Foundry*, Jan., 1898.

The Molder's Hot Spot. R. D. Moore. Examples given illustrate points requiring skill. Ill. *Foundry*, Jan., 1898.

Economy in Melting. J. P. Pero. *Foundry*, Jan., 1898.

The Melting Ratio. W. F. Prince. Discusses the progress and improvements in the melting and cupola practice. *Foundry*, Jan., 1898.

Chemistry in Foundry Practice. S. S. Knight. *Foundry*, Jan., 1898.

The Chemistry of Foundry Practice. Ernst A. Sjostëdt. Paper to be discussed at Montreal meeting of the Federated Canadian Mining Inst. Notes. *Can. Min. Rev.*, Feb., 1898.

Cupola Linings. Linson H. de Voe. Read at meeting of the Foundrymen's Ass'n, Philadelphia. *Iron Age*, Feb. 10, 1898.

The Uses of the Blower in the Foundry. Walter B. Snow. Read before the New England Foundrymen's Assn. Discusses the design of fan blowers, their operation, and the different types employed in the foundry. *Iron Age*, Feb. 10, 1898.

Some of the Advantages of the Positive Pressure Blower Over the Fan

for Melting Iron. J. A. Caldwell. From a paper read at meeting of the New England Foundrymen's Assn. *Foundry*, April, 1898.

Modern Cupola Practice, with Special Reference to the Discussion of the Physics of Cast Iron. Bertrand S. Summers. Outlines the effects of the metalloids and the development of new ideas. *Trans. Amer. Inst. Min. Engs.*, Aug., 1898.

Changes in Foundry Mixtures. Eugene W. Smith. Read before the Western Foundrymen's Assn. *Iron Age*, Feb. 24, 1898.

Oxidation of Foundry Metals. Thomas D. West. Read before the Pittsburg Foundrymen's Assn., Jan. 31, 1898. A series of original tests. *Iron Trades Rev.*, Feb. 3, 1898.

Notes on Iron Founding. (Aus der Giesserei.) A. Ledebur. A discussion of the influence of the method of casting on the strength of cast iron, with comparisons of German and American data. *Stahl und Eisen*, March 1, 1898.

Some Variations in Cupola Design. Part first considers cupolas attempting to secure economy through the tuyere arrangement. Ill. *Iron and Coal Trades Rev.*, April 15, 1898. Serial. First part.

Multiple Molding. F. O. Farwell. Illustrated description of the writer's method. *Foundry*, March, 1898.

A Mustard Top Mold and the Process of Making It. A. H. Cleaves. Illustrated detailed description. *Amer. Mach.*, March 17, 1898.

Furnace Facts About Foundry Iron. Charles W. Friend. Read before the Pittsburg Foundrymen's Ass'n. *Iron Trades Review*, March 31, 1898.

The Recovery of Iron from Cupola Cinder. W. J. Keep. *Metal Worker*, May 28, 1898.

Necessity of Well Mixed Furnace Casts and Correct Pig Iron Analyses. Thomas D. West. Read at Cincinnati meeting of American Foundrymen's Ass'n. Advises the use of chemical analysis, and discusses the need of uniform casts of pig iron. *Iron Age*, June 16, 1898.

Foundry Appliances. S. H. Stupakoff. Read before the Pittsburg Foundrymen's Ass'n. The equipment of the modern foundry. *Iron Trades Review*, May 26, 1898.

Inspection of Castings. E. H. Putnam. Read at the Cincinnati meeting of the American Foundrymen's Ass'n. *Iron Trades Review*, June 23, 1898.

Malleable Iron.

The annealing of Cast Iron. Geo. C. Davis. General review. *Iron Age*, Jan. 13, 1898.

Malleable Cast Iron. George C. Davis. Read before the Philadelphia Foundrymen's Ass'n. Gives its early history. *Iron Age*, Oct. 13, 1898.

Annealing and Case-hardening. Joseph Horner. The first of a series of articles. Ill. *Mech. World*. Oct. 14, 1898. Serial. First part.

Steel: Physics and Metallography of Steel.

Metallography considered as a Testing Method. F. Osmond. Paper

read at the Stockholm Congress (Aug., 1897) of the International Asso-tion for the Testing of Materials. *Metallographist*, Jan., 1898.

The Microstructure of Steel and the Current Theories of Hardening, a discussion of the various papers on this subject which have appeared in the Transactions of the American Institute of Mining Engineers. *Metallographist*, Jan., 1898.

The Present Condition of the Theories of Hardening. H. le Chatelier, from *Revue Générale des Sciences*, Jan. 15, 1897, *Metallographist*, Jan., 1898.

Carbon and Iron. E. H. Saniter, from *Iron and Steel Institute*, Aug., 1897, *Metallographist*, Jan., 1898.

To Distinguish Iron from Steel When in Thin Sheets. Gus C. Henning. Ten tests quoted. *Amer. Mach.*, March 24, 1898.

On the Determination of Hardening Carbon and Carbide Carbon. H. Jüptner von Jonstorff. Abridged from *Journal of the Iron and Steel Institute*, 1897, No. 1. *Metallographist*, April, 1898.

Bibliography of the Metallography of Iron and Steel. Albert Ladd Colly. 142 titles. *Iron Age*, Jan. 27, 1898. Revised and 46 titles added. A. Sauveur. *Metallographist*, April, 1898.

Magnetic Properties of Hardened Steel. Mrs. Sklodowski Curie. From *Bulletin Société d' Encouragement pour l' Industrie Nationale*, Jan., 1898. *Metallographist*, April, July and Oct., 1898.

Steel and Iron Alloys. R. A. Hadfield. Paper read at the Institution of Civil Engineers, Engineering Conference, Section IV. *Metallographist*, April, 1898.

Evidence for the Allotropic Theory. H. M. Howe. *Metallographist*, April, 1898.

The Microstructure of Alloys of Iron and Nickel. (Sur la Microstructure des Alliages de Fer et de Nickel.) A preliminary note by M. Osmond. *Comptes Rendus*, May 9, 1898.

The Crystalline Structure of Iron and Steel. John E. Stead. A résumé of the more practical points of a paper presented at the meeting of the Iron and Steel Inst., London. *Iron and Steel Trades Jour.*, May 14, 1898 and *Metallographist*, Oct., 1898.

Progress in the study of Steel. (Les Progrès Realisés dans la Connaissance du Métal Acier.) Ad. Greiner. Discusses methods of testiug steel, and gives especial attention to peculiarities of physical constitution as revealed by metallography and microscopy. *Revue Universelle des Mines*, May, 1898.

On the Passage of Carbon Into Iron During the Cememtation Process. George J. Pitt. Read before the South Staffordshire Inst. of Iron and Steel Works Managers. An account of experimental study which seems to indicate molecular interchange. *Col. Guard.*, June 10, 1898.

The Micro-Structure of Iron and Steel. S. S. Knight. Read at Cincinnati meeting of the American Foundrymen's Ass'n. Ill. *Amer. Manuf. and Iron World*, June 17, 1898.

The Constitution of Steel Considered as an Alloy of Iron and Carbon. Albert Sauveur. From *Technology Quarterly*, June, 1898. *Metallographist*, July, 1898.

Allotropic Iron and Carbon. E. H. Saniter. From *Journal of the Iron and Steel Institute*, May, 1898. *Metallographist*, July, 1898.

The Hardening Power of Low Carbon Steel. H. M. Howe. *Metallographist*, July, 1898.

The Micro-Chemistry of Cementation. John Oliver Arnold. Read before the Iron and Steel Inst., at Stockholm. Describes the method and the micro-chemical analyses of a series of bars. *Iron and Steel Trades Jour.*, Sept. 3, 1898.

On the Diffusion of Sulphides Through Steel. E. D. Campbell. Read before the Iron and Steel Inst., at Stockholm. Experimental work, with statement of results. *Iron and Steel Trades Jour.*, Sept. 3, 1898.

The Solution Theory of Iron and Steel. Hans Jüptner von Jornstorff. Read before the Iron and Steel Inst., at Stockholm. The paper is a continuation of the writer's researches on the application of the laws of solution to the case of iron and steel. *Iron and Steel Trades Jour.*, Sept. 10, 1898.

The Physical Analysis of Steel. John Parry. Read before the South Wales Inst. of Engs. *Col. Guard.*, Sept. 23, 1898.

Influence of Arsenic Upon the Mechanical Properties of Steel. J. Marchal. *Bul. de la Société d'Encouragement*, Oct., 1898.

On the Signification of the Critical Points of Iron and Steel. F. Osmond. *Metallographist*, Oct., 1898.

Steel: Effect of Working.

Annealing.

On the Permanent Deformation and Rupture of Metals. (Sur les Deformations Permanentes et la Rupture des Metaux.) M. G. A. Faurie. *Comptes Rendus*, Jan. 31, 1898.

Annealing Malleable Castings. Alexander Cairns. Read at meeting of Foundrymen's Association, in Philadelphia. *Iron Age*, March 10, 1898.

Tempering by Color. B. F. Spalding. *Amer. Mach.*, June 2, 1898.

Effects of Heating and Working on Iron and Steel. H. E. Smith. *Jour. Association of Eng. Socs.*, March, 1898.

Modern Rolling Mills. John S. Hunting. Read before the West of Scotland Iron and Steel Institute. Types of mills, methods, and suggests considerations necessary in the construction and working. *Col. Guard.*, March 18, 1898.

Brittleness Produced in Soft Steel by Annealing. J. E. Stead. Read before the Iron and Steel Institute. Discusses peculiarity, cause and prevention. *Iron and Coal Trades Review*, Sept. 9, 1898, and *Journ. Amer. Soc. Naval Engrs.*, Nov., 1898.

Brinell's Chart of Changes of Fracture and Carbon in Steel. A graphic representation of changes in steel containing ¾ per cent. carbon while heating and cooling. *Eng. and Min. Jour.*, Dec. 24, 1898.

Nickel Steel and Special Steels.

Handling Tool Steel.. S. K. Stupakoff. Urges the use of a reliable pyrometer, and compulsory furnishing of analysis. *Iron Age*, Feb. 17, 1898.

Researches on Nickel Steel. (Recherches sur les Aciers au Nickel.) C. E. Guillaume. Investigations into the magnetic, thermal and physical properties of alloys of steel and nickel with details of the apparatus and results. *Bulletin de la Société d'Encouragement*, March, 1898, and *Comptes Rendus*, March 7, 1898.

Nickel Steel for Crank Pins and Axles. H. F. J. Porter. Condensed. Gives results of tests and shows its valuable qualities, which insure a combination of elastic strength and ductility. *Amer. Mach.*, March 24, 1898.

Open Hearth Steel.

The Defects of Steel Ingots. (Les Défauts des Ingots d'Acier.) A critical study of the defects caused by improper heat treatment and variations in composition and the influence of pressure, with best precautions to be observed for satisfactory results. Two articles. *Le Génie Civil*, Jan. 15 and 22, 1898.

Basic Refined Steel on the Continent. C. E. Stromeyer. From a paper read before the Institution of Engineers and Shipbuilders in Scotland. *Col. Guard.*, Jan. 28, 2898, and *Eng.*, June 17, 1898.

The Progress of Open-Hearth Cast Steel in Machine Construction. A. W. Discusses the improvement in methods and investigations needed to remove the uncertainty as to interior integrity. Ill. *Iron Age*, March 31, 1898.

Acid *vs.* Basic Steel. The views of two leading manufacturers as to the reliability. *Iron Age*, March 10, 1898.

The Rolling of Thomas Steel. (Le Laminage de l'Acier Thomas.) J. Magery. Description of the rolling mills of the plant at Roth-Erde, near Aix la-Chapelle. *Revue Universelle des Mines*, May, 1898.

Notes on the Bertrand-Thiel Process. James Hartshorne. Showing the developments and brief résumé of recently published articles. *Trans. Amer. Inst. Min. Engs.*, June, 1898.

Basic Slag in the Martin Process. (Thomas-schlacke im Martinbetrieb.) O. Thiel. An examination of the chemical composition of the slag. *Stahl und Eisen*, Aug. 15, 1898.

Bessemer Steel.

Re-Heating Furnaces for Iron and Steel. Fred. Mills. West of Scotland and the Northeast Coast. Ill. *Iron and Coal Trades Review*, April 22, 1898.

The Conditions in which Silicon and Chromium are found in Siderurgical Products. (Recherches sur l'Etat où se Trouvent le Silicium et le Chrome dans les Produits Sidérurgiques.) MM. Carnot and Goutal. *Comptes Rendus*, May 2, 1898.

Notes on the Tropenas Steel Process. Alexander Tropenas. Read at the Cincinnati meeting of the Amer. Foundrymen's Ass'n. *Iron Age*, June 16, 1898.

The Thermo-Chemistry of the Bessemer Process. Noel Hartley. Illustrates and describes various converters. *Jour. Soc. of Arts*, July 8, 1898. Three parts.

LEAD.

The Influence of Altitude on Smelting. Herbert Lang. An explanation of the increased fuel consumption. *Eng. and Min. Jour.*, Jan. 29, 1898.

Notes on the Mœbius Processes for Parting Gold and Silver, as carried on at the Guggenheim Smelting Works at Perth Amboy, N. J. Percy Butler. The plant is described and illustrated. *Can. Min. Rev.*, March, 1898.

Recent Smelting Practices in Colorado. By L. S. Austin. *Eng. and Min. Jour.*, March 5, 1898.

The Treatment of Complex Lead, Zinc, Silver, Sulphide Ores. O. J. Steinhart. A brief account of past work, with special reference to its most recent developments. *Industries and Iron*, March 24, 1898. Serial. 1st part.

Metallurgical Methods in Use at Broken Hill. G. H. Blakemore. Deals with smelting, lixiviation and chloridizing, almagamation and concentration. *Australian Min. Standard*, March 31, 1898. Serial. First part.

Silver Lead Blast Furnace Construction. H. V. Croll. Colorado and Utah. *Eng. and Min. Jour.*, May 28, 1898.

The Broken Hill Sulphide Problem. From remarks of William Dewar. *Eng. and Min. Jour.*, June 4, 1898.

Lead Smelting in the Joplin, Missouri District. E. Hedburg. Descriptions of the Scotch lead furnace, the Lewis Bartlett process at the work of the Picher Lead Co. Ill. *Mines and Minerals*, July, 1898.

The Lang Smelting Furnace. Illustrated. *Eng. and Min. Jour.*, Aug. 6, 1898.

Recent Advances in Silver Lead Smelting. R. H. Terhune. Read at the Salt Lake session of the International Mining Congress. *Min. and Sci. Press*, Aug. 6, 1898.

Experiments in the sampling of Silver Lead Bullion. G. M. Roberts. At the Proprietary Mines, Broken Hill, N. S. W , for the purpose of ascertaining the relative accuracy of the methods used. *Trans. Amer. Inst. Min. Engs.*, Aug., 1898.

A proposed New Method of Smelting Lead Concentrates. Henry F. Collins. *Can. Min. Rev.*, Oct. 31, 1898.

The Ashcroft Process for the Treatment of Mixed Lead and Zinc Sulphide Ores. Walter Renton Ingalls. At Cockle Creek, N. S. W. Also editorial. *Eng. and Min. Jour.*, Oct. 22, 1898.

The Refining of Base Lead Bullion Containing Silver, and High in Gold. G. H. Blakemore. *Trans. Australian Inst. Min. Engs.*, Vol. V.

COPPER.

A Copper Wire Mill. The Waclark Manufacturing Company at Bay View, N. J. *Amer. Mach.*, Feb. 17, 1898.

The electrolytic Laboratory at the imperial Mining Academy at Leoben. (Die Elektrolytische Einrichtung an der k. k. Bergakademie in Leoben.)

Dr. H. Paweck. An account of the apparatus at the Austrian Mining Academy for instruction in electrolysis for separation of metals. Two articles, one plate. *Oesterr. Zeitschr. f. Berg-u-Hüttenwesen*, Feb. 19 and 26, 1898.

The Origin and Mode of Occurrence of the Lake Superior Copper Deposits. M. E. Wadsworth. A description of the geology with discussion of deposits, their origin, etc. *Trans. Amer. Inst. Min. Engs.*, Feb., 1898.

Purification of the Electrolyte in Copper Refining. A translation of the essential portions of a paper by Titus Ulke, which appeared in the *Zeitschrift für Elecktrochemie*. *Electrician*, Lond., Feb. 11, 1898.

Pyritic Smelting and Its Bearing on Certain South African Ores. D. Dörffel. *Jour. of Chemical and Metallurgical Soc.*, South Africa, April, 1898.

Conductivity in Mixed Solutions of Electrolytes. (Ueber Stromleitung in Gemischten Lösungen von Elektrolyten.) K. Hopfgartner. Showing the influence which various proportions of mixed electrolytes have upon the results of electrolytic analysis. *Zeitschr. f. Elektrochemie*, April 5, 1898.

The Electro-Analytic Separation of Silver from a Nitric Acid Solution, and its Separation from Copper. (Ueber die Elektro-Analytische Abscheidung des Silbers aus Salpetersaurer Lösung und die Trennung Desselben von Kupfer.) F. W. Kuster & H. von Steinwehr. Showing the results with different voltages and temperatures, and describing the methods employed. *Zeitschr. f. Electrochemie*, April 5, 1898.

A study of Examination of Impurities from Copper Mattes in the Reverbatory and the Converter. Edward Keller. A comparison of two methods, working on the same material. *Trans. Amer. Inst. Min. Engs.*, Feb., 1898. Also, discussion of this paper presented at the Atlantic City Meeting, Feb., 1898. *Trans. Amer. Inst. Min. Engs.*, June, 1898.

The Garretson Copper Smelting Furnace. Illustrated description, with letter from E. D. Peters, Jr. *Eng. and Min. Jour.*, Feb. 5, 1898.

The Extraction of Copper from Residues of Pyrites Burners. R. Helmhacker. Describes the Hoepfner method, and gives particulars of the plant of the Vitkovice Copper Extracting and Electrolytic Works in Austria. *Min. and Sci. Press*, April 16, 1898.

Improved Methods of Analysis. Titus Ulke. Determination of arsenic and antimony in electrolytic copper, of copper in slimes, and of copper and nickel in ores and furnace products. *Eng. and Min. Jour.*, April 9, 1898.

The Electrolytic Assay as Applied to Refined Copper. Additional discussion of George L. Heath's paper presented at the Lake Superior meeting, July, 1897. *Trans. Amer. Inst. Min. Engs.*, June, 1898.

Copper Production in 1897. The output in the United States reached the highest point ever attained. *Eng. and Min. Jour.*, June 25, 1898.

Progress in Electrolytic Copper Refining During 1897. Titus Ulke. From *The Mineral Industry*, Vol. VI. Brief review of improvements in mechanical details and chemical methods. *Eng. and Min. Jour.*, July 2, 1898.

Copper Smelting in Wales. A. Terril. Recent modification of older processes. *Eng. and Min. Jour.*, Dec. 3, 1898.

GOLD.

The Influence of the Anodes in Depositing Gold from its Cyanide Solution. E. Andreoli. *Eng. and Min. Jour.*, Jan. 22, 1898.

Temperature in Amalgamation. Editorial. The cooling of the water used in stamp mill batteries considerably increases the yield of gold. *Eng. and Min. Jour.*, Jan. 29, 1898.

The Stamp Milling of Gold Ores in its Relation to Cyaniding. E. H. Johnson. *Chemical and Metallurgical Soc. of South Africa*, Dec. 18, 1897.

Ore Treatment in Boulder County, Colorado. C. C. Burger. Describes a 50-ton chlorination plant with its machinery, and its adaptability to tellurium ores. *Eng. and Min. Jour.*, Jan. 29, 1898.

The Cyanide Process for Gold Ores in Western Africa. Thomas Tonge. Reviews development of process. *Eng. Mag.*, Jan., 1898.

Placer Mining by Machinery. William M. Johnston. Reviews some of the methods adopted which often have resulted in loss, and endeavors to point out lines which may be safely followed. *Min. and Sci. Press*, Feb. 5, 1898.

The Melting Points of Silver and Gold. (Sur les Points de Fusion de l'Argent et de l'Or.) New determinations by M. Berthelot, together with comparisons of his results with those of other authorities since 1863. The results are 962° C. for silver and 1064° C. for gold. *Comptes Rendus*, Feb. 7, 1898.

The Crystalline Structure of Gold and Platinum Nuggets. A. Liversidge. Abstract of a paper read before the Royal Society of N. South Wales. Illustrated description. *Eng. and Min. Jour.*, Feb. 19, 1898.

The Assaying of Gold Bullion. C. Whitehead and T. Ulke. The method used by the United States mints and assay offices in assaying "unparted bars." *Eng. and Min. Jour.*, Feb. 12, 1898.

The Dry Separation of Gold and Copper. Franklin R. Carpenter. Explains a separating process recently patented, and gives notes of literature examined and experiments made. *Eng. and Min. Jour.*, Feb. 12, 1898.

Absorption of Gold by Wooden Leaching Vats. Francis L. Bosqui. Observations tend to show that losses through this canse have been overestimated. *Eng. and Min. Jour.*, Feb. 26, 1898.

The Assaying of Silver Bullion. C. Whitehead and T. Ulke. An Explanation of Methods used. *Eng. and Min. Jour.*, Feb. 26, 1898.

Chemistry of the Cyanid Process. Reviews of theories. *Min. and Sci. Press*, March 12, 1898.

The Treatment of Tailings by the Direct-Filling Process. F. Cardell Pengilly. Abstract of a paper read before the Institute of Mining and Metallurgy, London. Describes this method as used at Witwatersrand. *Eng. and Min. Jour.*, March 19, 1898.

Mining the Gold Ores of the Witwatersrand. H. H. Webb and Pope Yeatman. A general description with illustrations of the plants at the

leading mines, and a description of machinery. *Engineering Magazine*, April, 1898.

Roasting Gold Ores. H. Van F. Furman. The chemistry of the process and the ores to which it should be applied. Ill. *Mines and Min.*, April, 1898. Serial. First part.

The Tailings Plant of the Montana Mining Company, Limited. C. W. Merrill. Illustrated description of the plant, with method of operating. *Eng. and Min. Jour.*, April 16, 1898.

The Minerals which Accompany Gold, and Their Bearing upon the Richness of Ore Deposits. T. A. Rickard. Abstract of a paper read before the Inst. of Mining and Metallurgy, London. *Eng. and Min. Jour.*, April 23, 1898.

The Stamp Milling of Gold Ore in its Relation to Cyaniding. E. H. Johnson. A continued discussion of this paper. *Jour. of Chemical ana Metallurgical Soc. of S. Africa*, April, 1898.

The Largest Cyanid Gold Reduction Works in the World. W. P. Hardesty. An account of the Golden Gate Mill of the De La Mar Mercur Mines Co., Mercur, Utah. Ill. *Eng. News*, May 19, 1898.

Cyanid, Chlorination and Amalgamation in Colorado. R. B. Turner. Condensed from report of State Bureau of Mines. Processes at Cripple Creek and various other points, with the cost and manner of applying. *Min. and Sci. Press*, May 21, 1898.

Milling and the Cyanid Process Arthur Lake. *Mines and Minerals*, May, 1898.

Notes on the Application of Oxygen in the Cyanid Process. H. T. Durant. Discussses the use of atmospheric or molecular oxygen, and the methods of application, with results of experiments. Ill. *Jour. of Chemical and Metallurgical Soc. of S. Africa*, May, 1898.

Stamp Mill Indicator Diagrams. Henry Louis. Method devised by Dr. B. Morison, which promises to be of value in determining the efficiency of a new mill. *Trans. Amer. Inst. Min. Engs.*, June, 1898.

Some Notes on the Recovery of Gold from Cyanide Solutions. S. C. Coles. Extraction results with aluminum cathodes and iron anodes with varying strength solutions of gold cyanide. *Min. and Sci. Press*, June 11, and Nov. 26, 1898.

The Cassel-Hinman Gold and Bromine Recovery Process. Editorial discussion of this new process. The company's statements need careful investigation before meriting the attention of investors. *Eng. and Min. Jour.*, June 18, 1898.

Scorification and Cupellation Without Muffle. A New Furnace and Method for Gold and Silver Assays. George A. Koenig. Ill. *Trans. Amer. Inst. Min. Engs.*, June, 1898.

Gold Milling in Colorado. John Rogers. General description of three gold mills recently erected in Colorado. Ill. *Eng.*, July 1, 1898. Serial. First part.

The Cyanid Process. Louis Fade. Read before the International Mining Congress at Salt Lake City. Discusses ore treatment, crushing, sorting, etc., the Elsner theory, and the success of the process. *Min. and Sci. Press*, July 16, 1898.

The Cyanid Process as Applied on the Rand. W. Leonard Holms. A fully illustrated account. *Engineering Magazine*, July, 1898.

The Assay of Telluride Ores. Charles H. Fulton. Describes experiments to determine the difficulty and losses and the selection of proper methods and precautions to remedy these defects of the assay. *School of Mines Quarterly*, July, 1898.

Analyses of Cyanide-Mill Solutions. W. J. Sharwood. Gives analyses made in the laboratory of the University of California, describing methods. *Eng. and Min. Jour.*, Aug. 20, 1898.

Cyanide Experiments upon Dry Ores of Southern Slocan District. W. S. Johnson. Results of experiments. *Can. Min. Rev.*, Aug., 1898.

Practical Cyanidation of Tailings and Ores. Alfred S. Edgecombe. Remarks on the practical treatment in Australian experience. *Can. Min. Rev.*, Aug., 1898.

The Siemens and Halske Process in the Transvaal. (Der Siemens and Halske Prozess in Transvaal). H. Pauli. Showing the extent to which the process has been introduced, and its advantages over the MacArthur-Forrest process. *Zeitschr. f. Elektrochemie*, Sept. 1, 1898.

Microscopic Structure of Gold and Gold Alloys. Thomas Andrews. Experiments to determine the micro-physical structure. Part first. Ill. *Eng.*, Sept. 30, 1898.

Smelting Gold and Silver Ores in Colorado. Thomas Tonge. The locations and capacities of the plants and statistics in regard to their output and effects on the mining business. Ill. *Mines and Min.*, Oct., 1898.

Notes on a Labratory Amalgamating Device and Comparisons with Actual Mill Results. H. A. Guess, *Can. Min. Rev.*, Oct. 31, 1898.

A Zinc Process for Precipitating Gold from Weak Solutions. T. L. Carter. *Jour. Chem. and Met. Soc. of S. Africa*, Oct., 1898.

Discrepancies in Slime Treatment. W. A. Caldecot. *Jour. Chem. and Mech. Soc. S. Africa*, Oct., 1898.

Treatment of Gold Ores on the Hanraki Peninsular, New Zealand. A. H. Bromley. Describes some typical plants. *Eng. and Min. Jour.*, Nov. 12, 1898.

The Stamp Milling of Gold Ores in its Relation to Cyaniding. Discussion of paper by E. H. Johnson. *Chemical and Metallurgical Soc. of South Africa*, Jan. 29, 1898.

Slime Treatment in Montana. M. T. Alderson. Silver Star. *Eng. and Min. Jour.*, Dec. 24, 1898.

The Mining and Minting of Gold and Silver. A. E. Outerbridge, Jr. Review of coining processes, etc., of last thirty years. *Jour. Frank. Inst.*, Dec., 1898.

ALUMINUM.

Mechanical Properties of Certain Aluminum Alloys. R. C. Carpenter. Facts determined at the laboratories of Sibley College, Cornell University. *Amer. Soc. of Mech. Engs.*, June, 1898.

Aluminum Manufacture, with Description of the Rolling Mills and Foundry at Milton, Staffordshire. E. Ristori. Read before the Inst. of Mech. Engs. at Derby, England. *Eng.*, July 29, 1898.

The Impurities of Aluminum and of Its Alloys. P. Defacqz. A paper presented to the French Academy by M. Moissan. *Comptes Rendus*, Dec. 27, 1897.

ALLOYS.

Microscopic Study of Metallic Alloys. G. Charpy. From *Bulletin Société d' Encouragement pour l' Industrie Nationale*, March, 1897. *Metallographist*, April and July, 1898.

Alloys. Prof. Roberts-Austen. Lecture to the Society of Arts, March 15, 1897. Four Cantor Lectures, *Journal of the Society of Arts*, Oct. 22, 1897. *Metallographist*, April, July and Oct., 1898.

Experimental Researches on the Metallic Alloys. (Recherches Expérimentales sur las Alliages Métalliques.) G. Charpy. Devoted to the white antifriction alloys, with information and tables; the whole forming a part of the work of the Commission on Alloys. *Bulletin de la Societe d'Encour.*, June, 1898.

Micro-Chemical Examination of Lead-Antimony Alloys. John E. Stead. From *Journal Soc. Chemical Industry*, March and June, 1897. Abridged. *Metallographist*, July, 1898.

The Constitution of Ternary Alloys. (Sur la Constitution des Alliages Ternaires.) Georges Charpy. A micrographic examination of alloys of lead, tin, and bismuth, showing how the different constituents are arranged in the alloy. *Comptes Rendus*, June 6, 1898.

The Microstructure of Bearing Metals. Guilliam H. Clamer. Study of structure and composition of bearing metals with the conclusion that an alloy of the proper proportions of copper, tin and lead seems best suited for railroad service. Discussion. Ill. *Jour. Franklin Inst.*, Aug., 1898.

The Micro-Structure of Bearing Metal. Quotes conclusions of Dr. Dudley. *R. R. Gazette*, May 13, 1898.

A New Method of Generating High Temperatures. (Ueber ein Neues Verfahren zur Erzeugung Hoher Temperaturen.) Dr. H. Goldschmidt. The process is based on the fact that aluminum develops a high temperature in entering into combination, and hence raises the temperature when used as a reducing agent. *Stahl und Eisen*, May 15, 1898; and *Amer. Manuf. and Iron World*, July 1, 1898, and *Zeitschr. d. Ver Deutscher Ing.*, Sept. 10, 1898.

Aluminum for High Temperatures and for the Reduction of Metals from their Oxides. J. B. Nau. Describes the method of Hans Goldschmidt for the extraction of metals from their oxides by means of metallic aluminum. *Iron Age*, June 16, 1898, and Oct. 6, 1898.

ELECTROMETALLURGY.

Electrometallurgy in the Iron Industry. (Elektrometallurgisches für die Eisenindustrie.) Dr. W. Borchers. A paper before the Düsseldorf Convention of the *Verein Deutscher Eisenhüttenleute*, showing the applicability of the electric furnace to the iron industry. Ill. *Stahl und Eisen*, April 1, 1898.

Electric Smelting Furnaces. (Elektrische Schmelzöfen.) C. Häussermann. A general descriptive article of the various forms. *Zeitschr. d. Ver Deutscher Ing.*, April 16, 1898.

Electric Smelting. W. S. Horry. Abstract of paper read before the Northwestern Electrical Ass'n giving results of investigations. *Electrical World*, June 25, 1898.

Applications of the Electric Furnace in the Iron Industry. (Les Applications du Four Electrique dans l'Industrie du Fer.) Emile Demenge. Giving many illustrations of historical furnaces, as well as projected devices for iron manufacture. Two articles. *Le Génie Civil*, July 30, Aug. 6, 1898.

The Electric Furnace. F. Jarvis Patten. Describes early historical forms, and recent improvements. Ill. *Electrical World*, Oct. 22, 1898.

NICKEL.

The Occurrence and Production of Nickel in the United States. Perry F. Nursey. *Industries and Iron*, June 10, 1898.

The Mining, Smelting and Refining of Nickel. Titus Ulke. Methods and costs of nickel production. *Engineering Magazine*, Nov., 1898.

GENERAL.

Abstracts and Metallurgical Note References for Year 1898. Jos. Struthers. *School of Mines Quarterly*, April, 1898.

Between the Mine and the Smelter—A Lecture Delivered Before the Graduating Class of the School of Mines. Albert R. Ledoux. Discusses problems affecting transportation when the smelter is located at a distance from the mine; also the questions of sampling and assaying. *School of Mines Quarterly*, July, 1898.

The Possibilities for Smelting in British Columbia. R. A. Hedley. Read before the Federated Can. Min. Inst. Information concerning the character of the ores and cost of smelting. *Can. Eng.*, June, 1898.

MINOR METALS.

The Influence of Antimony on the Cold Shortness of Brass. Erwin S. Sperry. Results of Experiments. Ill. *Trans. Amer. Inst. Min. Engs.*, Feb., 1898.

Improved Brass Furnaces. D. C. Thompson. Description, with illustrations. *Foundry*, Feb., 1898.

"Burning in" Brass Castings. C. Vickers. Directions and suggestions for "burning in" successfully. Ill. *Machinery*, N. Y., March, 1898.

Brass-Melting Furnaces. Joseph Horner. Part first deals with the mixing metal, and methods of making brass. *Mech. World*, April 22, 1898. Serial. First part.

A Talk on Brass Founding. Charles Vickers. Read at Cincinnati meeting of Amer. Foundrymen's Ass'n. *Iron Age*, June 16, 1898.

Brass Foundry Practice. K. K. Illustrated description of methods used. *Foundry*, June, 1898.

The Influence of Bismuth on Brass, and its Relation to Fire-Cracks. Erwin S. Sperry. Describes experiments giving results and conclusions. Ill. *Trans. Am. Inst. Min. Engs.*, Aug., 1898.

SMELTING.

Zinc Smelting in the Joplin District. E. Hedburg. Ill. *Mines and Minerals*, Oct., 1898.

The Malay Tin Industry. *Iron Age*, Dec. 2, 1898.

The Treatment of Cobalt and Other Similar Ores. Walter J. May. *Col. Guard.*, Nov. 25, 1898.

DEPARTMENT OF METALLURGY, SCHOOL OF MINES, COLUMBIA UNIVERSITY, April, 1899.

ANALYTICAL CHEMISTRY.

BY ELWYN WALLER, PH.D.

Lubricants for Glass Stopcocks. Phillips (*J. Amer. Chem. Soc.*, XX.,). The formulæ given are as follows: Pure rubber, 70 parts; spermaceti, 25 parts; vaseline, 5 parts; also pure rubber 70 parts; yellow unbleached bees-wax, 30 parts.

The rubber should be pure and fresh. Melt the rubber first in a covered vessel, avoiding scorching, and then stir in the other ingredients hot.

Formaldehyde as a reagent. Vanino (*Berichte*, XXXI., 1763). Au or Ag may be quantitatively precipitated by adding formaldehyde, then a little NaOH solution, and warming on the water bath.

Test Papers (*Pham. J.*, IV., 226). Wurster's Dimethyl-paraphenyl diamine paper. Filter paper impregnated with this base. Indicator of ozone H_2S, etc.

Wurster's Tetramethyl-paraphenyl diamine paper. Paper impregnated with this base shows intense bluish violet color in presence of O_3 or H_2O_2 in neutral or acetic solution.

Geissler & Oliver, paper for albumin, etc., in urine. Paper dipped in; *a.* Picric and citric acid gives precipitate in presence of albumin.

b. Sodium tungstate and citric acid. Gives precipitate in urine in presence of albumin, mucin, uric acid, peptones, or creatinine.

For sugar in urine. Paper impregnated with indigo carnine and Na_2CO_3 solution. Afford the Mulder reaction (successive green, red and yellow coloration).

Palladium chloride paper. Shows reduction of metallic Pd with coal gas, H_2S, CH_4, CO, etc.

Phloroglucin vanillin paper. (Saturated with alcoholic solution.) Serves to detect free HCl in gastric juice. Also, turns red when applied to negative pole of an electric current.

Fuchsin paper. (Alcoholic solution used on the paper.) Detects H_2SO_4.

Boettger's test paper. Saturated with neutral $AuCl_3$, colored violet in presence of ozone.

Cobalt paper. Paper impregnated with $CoCl_2$ and methyl blue solution. Indicator of Zn, Cu and Ni.

Preparing alkalimetric solutions. Marshall (*J. S. C. I.*, XVIII., 4). The author recommends as the most accurate and expeditious method, taking the Sp. gr. of H_2SO_4 (Conc. diluted with about half its volume of water), weighing out and diluting as determined by calculation. The temperature at which the Sp. gr. is taken (with Sprengel tube of 25 cc. capacity) should be 18° C. or 15° C. or 15.5° C. It must be correct within 0.5° C. The Sp. gr. must be determined within 0.0005.

Then percentage H_2SO_4 = 86 × Sp. gr. at 15° — 69.00 for 15°.
" = 86 × Sp. gr. at 15.5 — 68.97 for 15.5°.
" = 86 × Sp. gr. at 18 — 68.82 for 18°.

If P = percent H_2SO_4 in the acid determined as above and
A = gms. H_2SO_4 per litre required for standard,
n = number of litres wanted.
W = gms. of acid to be weighed out.

$$W = n A \times \frac{100}{P}.$$

Weigh out W gms. of acid, and dilute to n litres.

Standardizing alkalimetric solutions. Sorensen (*Zts. Anal. Chem.*, XXXVI., 639). $Na_2C_2O_4$ is recommended. It contains no water of crystallization, can be heated to 125°–150° without change, and is not hygroscopic. It is readily converted to Na_2CO_3 by ignition in a tightly covered platinum crucible.

To make a suitable article, dissolve 1 part commercial $Na_2C_2O_4$ in 32 parts water, render slightly alkaline with NaOH, and let stand until perfectly clear and bright. Filter and evaporate to one-tenth of its original volume. Cool and crystallize out; wash with cold water. A second crystallization affords a very pure product.

Ammonia in a gaseous atmosphere. Deniges (*Bull. Soc. de Pharm.*, March, 1898). NaBrO solution on a rod gives a copious evolution of bubbles of N. With primary fatty amines it shows a white yellow precipitate. No sensible reaction with secondary and tertiary amines.

Nessler solution Kermes-red with ammonia, yellow precipitate with monomethylamine, white with monethylamine, yellow if the reagent is in excess; also, white with di-methyl- and di-ethylamine, with tri-methylamine white precipitate, rapidly becoming brown.

$Hg_2(NO_3)_2$ black with NH_3 or fatty amines.

Hæmatoxylyin carmine color with NH_3.

Formol affords hexamethyline tetramine, which gives a yellow precipitate with bromine water acidulated with acetic.

Caustic Soda. Dobriner and Schranz (*Zts. f. Augen. Chem.*, XVI., 455). In estimating both caustic and carbonate, the method with $BaCl_2$ (adding that reagent, filtering out $BaCO_3$ and titrating the filtrate) gave high results for carbonate when toughened filter papers were used, as the paper absorbed alkali. With ordinary papers this was not the case. A satisfactory method was found to be: Dissolve 2.65 gms. in 50 cc. of water, add phenol-phthalein and titrate with normal H_2SO_4. Then add 3 cc. of normal acid, boil out CO_2 and titrate back with normal NaOH.

The first titration gives all NaOH and half the Na_2CO_3; the second gives the other half of the Na_2CO_3.

Rapid method for calcium. Passon (*Zts. Angen. Chem.*, 1898, 776). Dissolve the substance in dilute aqua regia, make up to 500 cc., and draw off an aliquot portion. Add a drop or two of phenolphthalein, and then ammonia until there is a perceptible pink color. Then add citric acid (10 per cent. solution) until the pink color is removed, and the precipitate disappears, then 10 cc. more. On dilution and boiling, the addition of $(NH_4)_2C_2O_4$ precipitates CaC_2O_4 cleanly, without necessity for previous separation of Fe Al P_2O_5, etc.

Free Lime in Set Portland Cement. Ljamin. *Analyst*, XXIII., 277. Certain crystals in the set cement consisting of $Ca(OH)_2$ may be seen by polarized light (dark with crossed nicols). The amount may be estimated by grinding finely and then sieving into a Hanenschild apparatus. On treating the powder with benzine and methylene iodide of Sp. gr. 3.34 and placing under the receiver of an air pump to remove air bubbles the heavier portions sink, but $Ca(OH)_2$ floats and may be collected and weighed. The impurities which float with it amount to only about 0.5 per cent. of the whole.

Another method depends on the fact that $Ca(OH)_2$ only parts with H_2O at 450° to 480°, whereas the other constituents of Portland lose water at about 160° C. One portion of the cement is heated 3 hours at 180° to 200° C. In another CO_2 is determined, and in a third total volatile matter by strong ignition. Loss in the first case is H_2O other than that combined as $Ca(OH)_2$. In the third case is CO_2 + total H_2O. The two methods afford closely agreeing results.

Chromium and Vanadium in Rocks. Hillebrand (*Am. Chem. Soc.*, XX., 454). Fuse 5 gms. of the pulverized rock with 30 gms. Na_2CO_3 and 3 gms. $NaNO_3$. Extract the melt with water, add alcohol to reduce Na_2MnO_4; nearly neutralize with HNO_3. Avoid making acid, as the liberated nitrogen oxides may reduce V_2O_5. Evaporate to approximate dryness, to remove SiO_2 and Al_2O_3. This precipitate always contains some Cr, and requires to be treated with H_2SO_4 and HF to expel SiO_2, the residue being fused again with Na_2CO_3 and $NaNO_3$, and leached out as before. After filtering the combined solutions, add $Hg_2(NO_3)_2$ which will precipitate Cr, Vd, Mo, W, P and As, together with some carbonate. Filter and wash the (bulky) precipitate, dry and ignite in Pt. crucible, then fuse with a little Na_2CO_3, extract with water, making filtrate and washings up to some convenient bulk (50 cc. or 100 cc.). Determine Cr. colorimetrically by color comparison with standard solutions of K_2CrO_4, to which has been added a little Na_2CO_3. For standard solutions one can use one containing 0.25545 gm. K_2CrO_4 per litre, (1 cc. = 0.0001 Cr_2O_3) and one of twice that strength. By measured dilutions one can match the tint of the solutions obtained from the samples. After this put the solution in a pressure bottle, acidify with H_2SO_4. Saturate with H_2S, close up and immerse in boiling water, to precipitate As_2S_5 and MoS_2. Tests for Mo may be applied to the precipitates. In the filtrate pass a current of Cl_2 and boil to expel H_2S, and then titrate Vd at 70° to 80° with standard K_2MnO_8, diluted so that 1 cc. = 0.001 gm. Vd_2O_5. Check by reducing with SO_2, and re-titrating.

Separating Titanium from Iron. Walker (*Jour. Am. Chem. Soc.*, XX., 513). Addition of large excess of H_2O_2 to a solution containing Ti affords the well-known yellow solution from which (if kept cold) ammonia fails to percipitate the Ti. This is not the case with Fe. The separation is on this basis: The H_2SO_4 solution of the two (about 150 cc.) is mixed with 100 cc. of H_2O_2 (about 2½ per cent.) solution; and then run slowly into a rather large casserole containing 100 cc. H_2O_2 solution and 30 cc. strong ammonia, stirring constantly. Filter at once and wash with ammonia containing H_2O_2. Dissolve the precipitate in HCl with H_2O_2 and repeat the operation. A third treatment practically effects complete separation.

Separating Iron from Zirconium, etc. Matthews (*J. Am. Chem. Soc.*, XX., 846). The $Na_2S_2O_3$ precipitation of ZrO_2 does not give a precipitate absolutely free from Fe. But if the two are converted to chlorides, the water evaporated off and the residue treated with ether, (containing HCl gas) all Fe in form of Fe_2Cl_6 was extracted. The method was found to be applicable to many others of the rare earths.

Specifications for Car Wheels (Chilled Iron). Davis (*J. S. C. I.*, XVII., 1116). The result of a number of analyses, combined with "Drop" test, "Thermal" test and "Service" test, indicate that the chemical composition should come within the following limits:

Graphite,	2.75 to 3.00 per cent.
Combined carbon,	0.50 to 0.75 " "
Silicon,	0.50 to 0.70 " "
Manganese,	0.30 to 0.30 " "
Sulphur,	0.05 to 0.07 " "
Phosphorus,	0.35 to 0.45 " "

Total carbon should run about 3.50 per cent. and Si and Mn together 0.9 to 1.00 per cent.

Iron and Steel: Rapid methods. Campredon (*Monit Sci.*, XII., [4] 778). *Iron.* Dissolve in H_2SO_4, boil out H, add a little $NaHCO_3$ to give an atmosphere of CO_2 in the flask, and titrate with $K_2Mn_2O_8$. Time, 10 to 15 minutes. Accuracy to 0.15 per cent.

Total Carbon. Carnot's method with 2KCl, $CuCl_2$. Determine CO_2 eudiometrically by Wiborg's method. Time, about 2 hours. Accuracy within 0.1 per cent.

Graphitic Carbon. Separate by HNO_3, and then apply Wiborg's method as above. Time, about 2 hours. Accuracy to 0.1 per cent.

Combined Carbon. By difference or by Eggert's method. By this method 10 or 20 steels may be tested in an hour. Accuracy within 0.01 per cent.

Manganese. When under 1 per cent. use Schneider's process. (Conversion to $H_2Mn_2O_8$ by Bi_2O_4 and tritation with H_2O_2.) Time, 10 to 15 minutes. Accuracy to 0.01–0.02 per cent. When over 1 per cent.: Dissolve so as to get Fe_2Cl_6 and $MnCl_2$, add excess of ZnO to precipitate $Fe_2(OH)_6$, titrate with $K_2Mn_2O_8$ (Volhard process). Time, 10 to 15 minutes. Accuracy to 0.025 to 0.25 per cent.

Sulphur. Rollet-Campredon method. Dissolve in HCl with a little H_2SO_4, pass the gas mixed with CO_2 and purified H through a red-hot

tube to convert all volatile S compounds to H_2S. Pass the gases through acidified Zn $(C_2H_3O_2)_2$. Then add excess of I solution $ZnS + I_2 = ZnI_2 + S$, and titrate back excess of I by standard $Na_2S_2O_3$. This method is used in many of the French works. Time: for iron and steel, 15 minutes; cast-iron, 25–30 minutes. Accuracy: for samples containing 0.1 per cent. or less; within 0.005 per cent., if over 0.1 per cent.; within 0.01 per cent.

Phosphorus. (Pittsburg method.) Dissolving in HNO_3; oxidizing hydrocarbons, etc., by $K_2Mn_2O_8$; removing lower Mn oxides by addition of sugar; precipitation by molybdate; finally acidimetric titration of the precipitate. Time, 15 to 20 minutes; accuracy; if under 0.1 per cent., within 0.005 per cent.; if over 0.1 per cent., within 0.01 to 0.02 per cent.

Arsenic. Dissolve in HNO_3, evaporate to dryness, take up with HCl, add $FeCl_2$ and distil over $AsCl_3$. Neutralize distillate with $(NH_4)_2CO_3$ and titrate with standard I solution. Time, 2 hours; accuracy to 0.005 per cent.

Silicon. For grey pig, dissolve in $HCl + KClO_3$, evaporate to dryness, filter, etc. Time, about 1 hour; results usually a little high.

For white pig, steel or iron samples. Drown's method—solution in HNO_3 and H_2SO_4, etc. Time, about 2 hours; accurate.

For Ferro-silicon or Silicon-Spiegel. Treat with HCl containg Br. When metal appears to be dissolved add H_2SO_4, evaporate to fumes, etc.

Copper. Dissolve in H_2SO_4. When dissolved dilute to 250 to 300 cc., add gradually 3 gms. $Na_2S_2O_3$ in crystals, keeping the solution at a boil until clear. Filter, wash and ignite the Cu_2S, dissolve in HNO_3, precipitate out Fe if present by ammonia, acidify with $HC_2H_3O_2$ and determine Cu by KI process. Time, 1 hour; accuracy within 0.005 per cent.

Chroninum. Stead's method. Oxidation by $K_2Mn_2O_8$ and then titration of the CrO_3 formed. Time (for steels), about 1 hour; accuracy to 0.05 per cent.

In the case of ferro chromes it may be necessary to attack the metal by Na_2O_2 in a nickel crucible.

Electrolytic separation of Iron from Manganese. Engels (*L'eclairage Electr.*, XIV.). The solution is placed in a platinum dish serving as a cathode. This is connected by means of a siphon with a glass vessel of dilute H_2SO_4 into which dips a platinum foil, serving as anode. Through this is passed a current of H during the operation. Current 0.4 to 0.8 amp. and 40 to 60 volts. Time, about 13 hours. About every hour the anode is removed, washed with water, and the MnO_2 formed removed with the aid of $H_2C_2O_4$ solution. Eventually two solutions are obtained, one containing all the Fe, the other containing all the Mn.

Manganese in ferro-manganese and Spiegel. Daw (*Ch. News*, LXXIX., 25). The Volhard method is found to be satisfactory when sufficient iron is present and when not too large an excess of ZnO is used. The process which succeeded best in the hands of the author was: Dissolve 0.5 gm. of the sample (Spiegel or ferro-manganese) in a 16 oz.

Phillips beaker with 30 cc. HCl, together with a little HNO_3. In the case of ferro-manganese, 0.4 gm. of iron wire is also added, to give sufficient Fe. After dissolving, 15 cc. of 50 per cent. H_2SO_4 is added, and the mixture evaporated to strong fumes of SO_3. After cooling and diluting, the solution is transferred to a litre Erlenmeyer flask. After dilution to about 500 cc., the acid is partially neutralized with Na_2CO_3 and then ZnO gradually added until the iron is all precipitated, avoiding a large excess of ZnO, bring to a boil and titrate with standard $K_2Mn_2O_8$ until the solution after partial settling shows a faint pink. The standard $K_2Mn_2O_8$ used contained 10 gms. of the salt per litre, standardized by use of a ferro-manganese of known composition.

Manganese estimation. Martha Austin (*Am. Jour. Sci.*, V., 206 and 382). Precipitation by $(NH_4)_2CO_3$ in presence of an excess of NH_4Cl (Guyard's method) was found to be complete. By igniting the carbonate, and afterward converting to sulphate for weighing (by heating with a few drops of conc. H_2SO_4), excellent results were obtained. The crucible containing the $MnSO_4$ should be finally heated to expel excess of H_2SO_4 when supported inside of a larger crucible.

Manganese precipitated by chlorate. Gooch and Austin (*Am. Jour. Sci.*, V., 260). The composition of the precipitate is not entirely MnO_2, but by suitable treatment (too elaborate for the ordinary needs of a commercial laboratory) it can be brought to that composition, and then estimated by KI and $Na_2S_2O_3$.

Manganese as pyrophosphate. Gooch and Austin (*Am. Jour. Sci.*, VI., 233). It is noted that frequently the precipitate which should be $MnNH_4PO_4$ consists partially or reverts to the form $Mn_3(PO_4)_2$. Experiments as to promoting the entire conversion to the ammonia compound by the action of ammonia rather increased than helped to avoid the difficulty. The use of NH_4Cl in the proportion of about 50 to 1 of the phosphate, provided sufficient excess of the precipitant (alkaline phosphate) were present, facilitated the formation of the desired compound. NH_4NO_3 seemed much less efficient.

Manganese separation, use of HF. Ford and Bregowsky (*Jour. Am. Chem. Soc.*, XX., 504). After precipitating MnO_2 by $KClO_3$ in the usual manner for the Ford method, a few drops of HF are added and then boiled off. By this means the SiO_2 protecting the graphitic carbon is removed, and further addition of $KClO_3$ and boiling effects the destruction of the graphite and gives a precipitate which filters readily. The use of HF is advantageous both with manufactured irons and with ores. For standard solution to reduce the MnO_2 preference is given to $FeSO_4$ solution over $H_2C_2O_4$.

Zinc and Manganese. Estimation as sulphides. Murmann (*Monatsh. f. Chem.*, XIX., 404). Good results may be obtained by precipitating these elements, as sulphides and ignition in a current of H. The difficulty is in filtering out cleanly and thorough washing. These difficulties are removed by addition of a little $HgCl_2$ to the solution. The HgS in the precipitate is readily removed in the ignition.

Reaction of Nickel and Cobalt. Papasogli (*L'Orosi*, XXI., 265). If to a mixture of Ni and Co salts, saccharose and NaOH are added, the Ni gives a greenish precipitate, while Co gives a violet coloration. Each

reaction is hindered by the presence of too large an excess of the other metal. In that case filter and test the filtrate with Amyl. sulph carbonate Yellow green color for CO, or $(NA_4)S$ brown coloration. Dissolve the precipitate in NH_4OH, and add Amyl. sulph. carbonate. Ni gives a bluish red color.

Separation of Nickel from Cobalt. Havens (*Amer. Jour. Sci.*, VI., 396). The metals in the form of chlorides (0.3 to 0.4 gm.) are dissolved in as little water as possible, to which are then added 10 to 15 cc. of ether, and the beaker containing this mixture is surrounded by ice water and saturated with gaseous HCl. $CoCl_2$ remains in solution, while yellow $NiCl_2$ remains insoluble. The presence of more than very limited amounts of water allows the solution of some of the Ni.

Arsenic in Metallic Antimony, Etc. Ducru (*C. Rend.*, CXXVII., No. 4. 1898). About 5 gms of the material coarsely powdered is placed in a retort or flask, and to it is added 100cc. Fe_2Cl_6 solution and 100 cc. HCl (Sp. gr. 1.17) 100 cc. are distilled off, then 100 cc. HCl added to the flask and another 100 cc. distilled off. 300 cc. of distillate obtained in this way will carry over all As, even if 10 per cent. were present. Test by diluting and passing H_2S. This distillate must be distilled a second time in the same manner to leave behind some Sb which inevitably comes over. Addition of 50 to 100 cc. of conc. H_2SO_4 to the contents of the flask increases the rapidity with which the $AsCl_3$ is distilled off. The Fe_2Cl_6 solution contains about 150 gms. Fe (nails) per litre. The nails are dissolved in HCl, H_2S passed through, and after filtering the Fe is oxidized by passing Cl, the excess of which is expelled by passing a current of air.

Tin in Tin Salt. Fraenkel and Pasal (*Mitlh. Gewerbe Miss. Wien.*, VII., 227). To a solution of 0.2 to 0.4 gms. of the salt, add a few drops of HCl, and then 0.5 to 1 gm. of pure Al. Heat gently for about 30 minutes, when all Sn will be precipitated. Then add 10cc. of strong HCl, and warm until both metals are completely dissolved. Add KNa $C_4H_4O_6$ and $NaHCO_3$, until the reaction is alkaline and tritrate with standard I solution. Test analyses indicate that the method gives a sufficient approximation for commercial purposes.

Tin in ores (Electrolytic) Campbell and Champion (*J. Amer. Chem. Soc.*, XX., 687). Precipitation from an oxalate solution was found to be more satisfactory than from sulpho stannate. The method is as follows: Mix 1 gm. of ore intimately with 5 to 6 gms. of a mixture of equal parts Na_2CO_3 and S, and fuse, using a porcelain crucible inside of another crucible, the two being placed inside a chimney made of a Hessian crucible without bottom. Keep at a bright red heat for an hour, cool, leach out with 40 to 50 cc. of hot water, and filter, wash, and fuse the residue a second time in the same manner as at first. Unite the solutions and washings from both fusions. Render the solution acid with HCl, and boil out H_2S, reducing the bulk of the solution to 75 to 80 cc. Then add 10 cc. HCl (Sp. gr. 1.20), following that with Na_2O_2, a little at a time, to oxidize the SnS_2 to SnO_2. Boil and filter into a Pt dish, add NH_4OH until barely alkaline, then 50 cc. of a 10 per cent. solution of $NH_4HC_2O_4$. This will give a clear solution, which is electrolized over night with a current $ND - 100 = 0.10$ ampere and with 4 volts electromotive force.

Wash with alcohol, dry and weigh. A higher voltage gives a crystalline deposit not adhering perfectly to the dish.

Lead and antimony in tin foil. Seyda (*Zts. f. off. Chem.* III., 364).

For lead. Dissolve 10 gms. in HCl of 25 per cent., add HNO_3 of 25 per cent. to oxidize the Sn. Then add drop by drop 25 per cent. solution of NaOH until the solution is clear or only opalescent. Keep the solution nearly boiling, and add some precipitated S, and pass H_2S, until the solution is decidedly yellow. Let stand 24 hours, filter and wash with Na_2S solution. Long washing is necessary to remove all Sn. Heat the precipitate with HNO_3, and extract with HNO_3. Evaporate with H_2SO_4 for $PbSO_4$.

For antimony. Dissolve 5 gms. in conc. HNO_3 with 25 cc. water Evaporate to dryness in a porcelain crucible; dry at not above 100° C., since anhydrous SnO_2 and Sb_2O_4 are not readily attached by NaOH. Add the oxides a little at a time to NaOH in the state of fusion. Treat with 100 cc. of water, add one-third the amount of alcohol, digest and filter. Washing the antimonate with alcohol alone causes some to go into solution. The washing solution should contain 25 per cent. alcohol and 10 per cent. NaOH to avoid erroneous results.

Sn will be in solution, Sb in the precipitate. Further details are unnecessary.

Lead in ores. Schneider (*Oesterr. Zts. Berg. u. Hutten*, XLVI., 431). Decompose first with 10–15 cc. conc. HCl, then add 5 cc. HNO_3 and evaporate to disappearance of red fumes. Add 25 cc. of $H_2C_4H_4O_6$ solution (10 gms. of acid) warm for a time, then add 25 cc. strong ammonia, warm again, filter and wash. To the filtrate (about 300 cc.) add 50 c. H_2SO_4 (1:1) and heat until the precipitate settles. Filter and wash with 1 per cent. H_2SO_4. Dry, ignite and weigh $PbSO_4$. Under these conditions these conditions the filtrate and washings (500 cc.) contains dissolved 0.003 gms. $PbSO_4$, which amount must be added to the weight of the precipitate obtoined.

Analysis of Chrome-yellow. Willenz (*Bull. Assoc. Belge de Chim.*, XII., 163). Heat gently 1 gm. with 100 cc., dilute HCl 1:20. Wash by decantation through a filter with hot water.

In the filtrate estimate total Ca by precipitation as oxalate, and the SO_3 of $CaSO_4$ by means of $BaCl_2$. Ca over and above that necessary to form $CaSO_4$ is reckoned as $CaCO_3$.

Digest the insoluble residue wiith neutral or slightly alkaline $NH_4C_2H_3O_2$ to remove the $PbSO_4$, which is estimated by evaporating to dryness, adding H_2SO_4 and igniting.

The residue is then treated with solution of KOH (boiled ten minutes) to dissolve out $PbCrO_4$, which leaves behind $BaSO_4$ and clay.

Red Lead analysis. Baucher (*Petit. Monit de la Pharm.*, XLVII, 2651).

Foreign substances. Treat 10 gms. with 10 per cent. HNO_3 till all PbO is dissolved, then add invert sugar to reduce PbO_2. Settle, decant off solution, treat the residue again with HNO_3. Wash and dry on a weighed filter at 105°C. Amount should not be over 1.5 per cent.

PbO_2. Heat 10 gms. with 500 cc. HNO_3 (10 per cent.) for 4 hours. Settle, wash by decantation, filter, dry and weigh. Should be 22 to 24 per cent.

Free litharge. Digest 10 gms. on the water bath with 20 gms. Pb $(C_2H_3O_2)_2$ and 200 cc. water. Filter, wash and weigh. Loss is free PbO.

Calculate combined PbO from the data afforded above.

Ca if present will be found in the HNO_3 solutions, $BaSO_4$ in the insoluble residue.

Assay of Minium. Forestier process (*Zts. Angew. Chem.*, 1898, 176), adopted by the Second International Congress of Applied Chemistry.

For Impurities Treat 10 gms. in a flask with 10 gms. of sugar dissolved in 50 or 60 cc. of boiling water, with 10 cc. of HNO_3 of 36°. Heat until all red color has disappeared; filter off impurities and weigh.

For Pb_3O_4. Treat 1 gm. with 10 cc. $HC_2H_3O_2$ of 10° and 20 cc. of water to decompose and leave PbO_2. Heat 30 minutes on the water bath. Filter off PbO_2 and weigh or titrate by iodometric process. The author believes that HNO_3 partially decomposes PbO_2.

Volumetric for Copper. Mead (*Jour. Am. Chem. Soc.*, XX., 611). The Cu is brought into solution as sulphate, precipitated by SO_2 and KCNS, and the precipitate filtered off through asbestos and well washed. On heating this precipitate with KOH or NaOH, $Cu_2(OH)_2$ is obtained, which, after filtering on asbestos and washing, is thrown into an excess of $Fe_2(SO_4)_3$ solution to which dilute H_2SO_4 has been added. After warming, the solution is titrated with standard $K_2Mn_2O_8$.

Iron standard $\times$ 1.125 = Cu standard.

Oxygen in Copper. Lucas (*Bull. Soc. Chim.*, XIX., 795). Modification of Hampe's method. The $AgNO_3$ solution should be of 5 per cent. strength, and, after having been made up from the pure salt, is preserved in a red glass bottle. The copper should be in sheets of about 0.15 mm. thickness, and the surface carefully cleaned before weighing out for analysis. Subject 1 gm. to the action of 120 cc. of the $AgNO_3$ solution for 15 hours in *vacuo* without shaking. Filter through an asbestos filter and wash. Treat again with more $AgNO_3$ solution for 2 hours in *vacuo*.

After again filtering and washing, dissolve the Ag and Cu_2O in HNO_3, perecipitate out the first with HCl and determine the Cu electrolytically or colorimetrically. The weight of Cu multiplied by 1.689 gives that of the Cu_2O present in the sample.

Detecting Cadmium im presence of Copper. Frey (*Zts. Anal. Chem.*, XXXVII., 743). If a strip of filter paper is dipped into a solution containing both Cd and Cu salts, the Cu salts wets the paper to a certain height, but the portion above that height which is wetted shows the presence of Cd salt only (Schönbein's absorption). This may be applied as a qualitative test by pouring the diluted ammoniacal solution containing, or suspected of containing, both elements into the funnel-shaped end of slender U-tube, the other limb having been drawn to capillary tube. On this last is laid a disc of filter paper. When the paper has been wetted with a spot about 4 cm. in diameter it is taken off and exposed to fumes of $(NH_4)_2S$. The central spot will show black from CuS, outside of which will be a yellow ring if Cd is present.

Bismuth-Qualitative. Heath (*Gaz. Chem. Ital.*, XXVIII., 393). A small amount of Bi-compound in the loop of a platinum wire when mois-

tened with Br or with conc. HCl and inserted in the lower part of the flame of a Bunsen burner gives a green coloration to the flame, similar to that produced by Cu, Bo or Tl compounds.

Bismuth determination. Vassine and Treubert (*Ber.*, XXXI., 1303). Formaldehyd solution is added, then a large excess of NaOH solution (of 10 per cent.). By heating on a water bath and frequent stirring, the metallic Bi which separates becomes agglomerated and can be readily filtered and washed. Wash finally with absolute alcohol on a weighed filter, and dry at 105° for weighing.

Volumetric for Mercury. Reichard (*Zts. Anal. Chem.*, XXXVII., 749). The Hg salt in solution is boiled with a known amount of standard solution of As_2O_3 in NaOH. The interaction will afford As_2O_5 and metallic Hg. On filtering off the Hg the excess of As_2O_3 remaining is determined by titration with standard I, or by $K_2Mn_2O_8$ solution.

Assay for Mercury. Chism (*Eng. and Min. Jour.*, LXVI., 86). The ore is mixed with clean iron filings, the mixture placed in a small crucible or an annealing cup, which is covered with a weighed picce of silver foil. On top of that is placed a silver or copper dish containing water. The crucible is set in a hole made in a piece of sheet tin. Heat is then applied to the lower part of the crucible containing the mixture. Hg is volatilized and caught on the silver foil. After heating for 10 minutes cool and weigh. Repeat until the Ag foil ceases to increase in weight.

Electrolytic Separation of Silver and Copper. Revay (*Zts. f. Elecktro Chem.*, IV., 313). *Acid solution.* In strong HNO_3 solution Ag is separated by a current of 1.3 to 1.4 volt (not above 1.4 volt). If the temperature is at 70° C. the deposit is not spongy.

Alkaline cyanide. The difference of potential varies as the Ag is precipitated. Ag is separated by a current of 1.7 to 1.8 volts, while Cu requires 2.3 to 2.4 volts.

Working with a solution at 50 to 60° C., with 1.6 to 1.8 volts current, separation of Ag was effected. The deposit is more coherent than that from the acid solution but the results are less exact. If a large excess of Cu is present some will precipitate at first.

Available Molybdenum in Molybdenum glauce. Bornträger (*Zts. f. Anal. Chem.*, XXXVII., 437). One gm. of ore is digested with 25 cc. HNO_3 in a flask for 2 hours. Dissolve out MoO_3 by ammonia, filter and treat the residue again with HNO_3 followed by ammonia. Combine the filtrates, evaporate to dryness, extract NH_4NO_3 by alcohol (50%), weigh MoO_3 on weighed filter, or determine by acidimetric titration.

Separation of Cerium and Thorium oxides. Wyrouboff and Verneuil (*Bull. Soc. Chim.*, XIX., No. 6). The order of these earths according to their analogies is Th, Ce, La, D, Vt (Er, Th). A method which will separate one term from the one immediately following, will separate it from all the rest which follow, and leave all those which precede.

Thorium phosphate is insoluble in dilute HCl, while cerium phosphate is easily soluble. This affords a method of separation, but the thorium phosphate is very voluminous, and difficult to filter and wash. The best method of managing is to evaporate the whole to a pasty consistency, take up with HCl diluted (1 : 7 or 8) and then filter and wash.

Cleve's reaction (H_2O_2) precipitates Th in sulphate solution as Th_2O_7, SO_3. H_2O_2 will give a similar precipitate of Ce in a sulphate or acetate solution. The latter compound is, however, more instable, being decomposed by HCl or HNO_3. In an *acetate* solution of the above-enumerated earths H_2O_2 will precipitate only Th and Ce. This precipitate, when converted to neutral nitrate and treated again with H_2O_2, will give only Th_2O_7, N_2O_5 as a precipitate. Described in this way the manipulation would seem simple, but the precipitates are so gelatinous that they cannot be easily washed or filtered. As a qualitative test, the reaction can be used. Th, if with the Ce, will show a cloudiness on addition of H_2O_2. Ce with Th imparts a yellowish tint to the precipitate with H_2O_2. For this purpose the test is very delicate.

To purify Ce from Th when the amount of the latter is very small the H_2O_2 reaction will serve in neutral solution of the nitrates. If the Ce salt contains 15 to 20 per cent. of Th, the major part of that element should first be removed by $(NH_4)_2CO_3$ and NH_4OH. To purify Th (for instance, in a solution of the earths from monazite), the neutral solution of the nitrates may be precipitated with H_2O_2—redissolve in HNO_3, evaporate to render neutral, dissolve up and reprecipitate. Repeat again to obtain it pure.

The H_2O_2 used should be freed from H_3PO_4 and H_2SO_4 by distilling. Hanriot's method (*Bull. Soc. Chim.*, XLIII., 468).

Perchlorate in Chili Salpetre. v. Brenkleveen (*Rec. trav. de Pays. Bas.*, XVII., 94). Addition of RbCl in presence of perchlorate affords rhombic crystals of $RbClO_4$ distinguishable under the microscope, especially after adding a drop of $K_2Mn_2O_8$ solution which colors the crystals strongly. 0.6 per cent. may be detected by this means. For smaller proportions it will be necessary to dissolve 10 gms. of the sample in 10 cc. of water, add 50 cc. of 95 per cent. alcohol, and after standing for the three hours examine the residue after addition of RbCl, the perchlorate being concentrated in the residue by this means.

Chlorates and Perchlorate in Chili Saltpetre. Foerster (*Chem. Ztg.*, 1898, 357). Mix 10 gms. of the sample with 10 gms. of dry Na_2CO_3 (free from Cl) and fuse together for 10 minutes. This converts all to chlorides. Dissolve in HNO_3 and determine total Cl in the sample. A test on another portion, not so treated, will give the Cl present originally as chloride.

Perchlorate in Alkaline Nitrates. Blattner and Brasseur (*Bull. Soc. Chim.*, [3] XIX., No. 12). Chlorides are first estimated by the ordinary (Mohn.) titration. Then 5 to 10 gms. of the sample are pulverized—mixed with 8 to 15 gms. pure CaO, and calchoid. After cooling the mass is dissolved in dilute HNO_3 and Cl determined by Volhard titration or gravimetrically. The difference represents Cl in percipitate.

Separating Iodine, Bromine and Chlorine. Carnot (*Bull. Soc. Chim.* [3], XIX., No. 6). With a mixture of these haloid salts, the addition of sulphuric acid charged with nitrous vapors separates only I, which can be taken up with CS_2 and removed in a separating funnel. In the solution addition of diluted H_2SO_4 and H_2CrO_4 with warming separates only Br, which may be removed with CS_2 as before. Addition of KI solution to this CS_2 frees its equivalent in I and the I and Br can be titrated separately by standard $Na_2S_2O_3$. In the solution from the Br separation, the Cl is precipitated by $AgNO_3$.

Sulphur in asphalt. Hodgson (*J. Amer. Chem. Soc.*, XX., 882). Four methods were tried on a number of samples. 1, Sealed tube (Carius); 2, Deflagration; 3, Peroxide; 4, Eschka's. The "Sealed tube" method appears to give most accurate results, but is more troublesome, and requires the longest time. "Deflagration" method results apparently low, longer than Nos. 3 and 4.

The Eschka method seems to be the better of the remaining two, as it requires less time and attention. The results by either "Peroxide" or "Eschka's" appear to be to all intents equally accurate.

Sulphur in coal. Study of methods. Heath (*J. Amer. Chem. Soc.*, XX., 630). The objection to the fusion method (Alkaline carbonate and nitrate) is the time necessary to evaporate and dehydrate the SiO_2 before proceeding to precipitation.

Eschka's method and that of Hundeshagen (which differs only in the use of K_2CO_8 where Eschka uses Na_2CO_8) are preferred, with the modification recommended by Mack and also by Handy—of completing oxidation by addition of Br water instead of by igniting with NH_4NO_8. In the case of bituminous coals the materials should be very thoroughly mixed, and the temperature raised very slowly. The use of H_2O_2 is not advised, on account of the frequent presence of small amounts of H_2SO_4 in that reagent.

If the products of fusion or of Eschka's method of treatment, are extracted with water before acidifying, thorough boiling for at least 10 minutes is necessary to extract all sulphate.

Silicon in Steel. Drown's method. Auchy (*J. Am. Chem. Soc.*, XX., 547). If aqua regia is used, the Fe is held in solution until the last moment, which favors the complete separation of the SiO_2. To effect this the steel is dissolved in nitro-sulphuric acid after the regular method, and then HCl is added, when the mixture is rapidly evaporated down on the hot plate.

Mixed Sulphides, Sulphates, Sulphites and Thiosulphate. Browning and Howe (*Am. Jour. Sci.*). Dissolve 0 1 gm. of the mixture in about 10 cc. or more of water. Add alkaline hydrate, to distinct, through faint alkaline reaction. Then add $Zn(C_2H_8O_2)_2$ in distinct excess, and filter. The precipitate contains *sulphide* which may be determined.

To filtrate add an excess of $HC_2H_8O_2$ and then $BaCl_2$, filter off *sulphate* as $BaSO_4$.

To filtrate add I solution until it shows a perceptible yellow tinge. This oxidizes sulphite to sulphate, and thiosulphate to tetrathionate. Add few drops HCl, decolorize by SnCl and filter off $BaSO_4$ which is calculated to *sulphite.*

Add Br water in slight excess, bleach by adding a little $SnCl_2$, and filter off $BaSO_4$, containing the S, originally as thiosulphate.

Bone Superphosphate. Poquillon (*Monit. Sci.* [4], XII., June, 1898). Bone superphosphate is sometimes adulterated with mineral phosphate. To detect such addition, some rely upon the nitrogen determination, which may easily be rendered fallacious. If, however, the fat is determined, it will be found that the ratio of 10 or 12 to 100 of P_2O_5 is characteristic of green bones, 6.5 per cent. for superphosphate made from bones extracted by benzene. Over 12 per cent. of fat (per 100 of P_2O_5) would indicate the use of bones from which fat had not been removed.

Distinguishing *mineral from animal phosphates.* Martinetti (*Stas. Sper. Agr. Ital.*, 1897, 993). The test is based on the proportion insoluble in HCl. The proportions are given thus:

Mineral phosphates	5.25 per cent.
Bone meal	0.90 per cent.
Bone ash	3. of silicates.
Mineral phosphate	1.20 of silicates.
Bone superphosphate	0.8 of silicates.
"Double" superphosphates	3. of silicates.
Mixtures of bone and mineral superphosphate	2.26 of silicates.

Carbon Monoxide in Air. Gautier (*C. Rend.*, CXXVI., 871). Of reagents adapted for the quantitative estimation of CO in air, I_2O_5 seems to be the only one promising to furnish a satisfactory method.

As qualitative reagents for minute quantities.

$AuCl_3$ which is easily reduced, or moist Ag_2O which the author believes gives Ag_4CO_3. The product on treatment with H_2SO_4 affords Ag_2SO_4, Ag and CO_2.

Report on Coal Analysis. Committee of Am. Chem. Soc. (*J. Am. Chem. Soc.*, XX., 281). The report submitted is more as a request for further information than as a formal report.

Sampling. At least 5 lbs. of an average sample should be taken, and quartered down to obtain the smaller sample for analysis.

Moisture. Dry 1 gm. in a bath jacketed with toluene for 1 hour at 104 to 107. Drying in vacuo seems to give results a little higher, probably more correct. The loss of volatile matter other than water appears to be less than 0.1 per cent.

Volatile Combustible. Place 1 gm. of (undried) sample in a Pt crucible of 20 to 30 gms. with close fitting cover. Heat over full flame of a Bunsen for 7 minutes. Carbon may be condensed on the under side of the cover, but should not be apparent on the sides of the crucible. The flame when burning free should have a length of 20 to 25 cm. Crucible should be 6 to 8 cm. from top of the burner. Loss is moisture and volatile C.

Ash. Burning off the portion used for moisture first with a low flame, and afterward increasing the heat, is more expeditious than burning off the coke from volatile carbon.

Fixed carbon by difference.

Sulphur. No recommendation. Comparative results by the various methods are requested.

Heating effect. No special apparatus is recommended. For approximate calculation the rule proposed by others is offered: Subtract from 100 the percents of moisture and ash, and half of the percent of S, and multiply the remainder by 80.7. The product is the heating effect in calories.

Volumetric for Boric acid. Copaux (*C. Rend.* CXXVII., 756).

Prepare: 1. Soda solution 10 gms. NaOH in 1 litre of water. Decarbonate by boiling with a little $Ca(OH)_2$.

2. Glycerin solution 2 vols. of 30 per cent. glycerine, with 1 vol. 95 per cent. alcohol.

3. Pure boric acid recrystallized and dried in vacuo over conc. H_2SO_4.

Dissolve the borate in as little water as possible, add methyl orange and titrate with standard HCl or H_2SO_4. This gives free alkali, as well as that combined with B_2O_3 (which does not affect methyl orange). Then add phenol phthalein indicator, and two volumes of the glycerin solution (No. 2) and titrate back with the NaOH solution (No. 1) until the alkaline color of phenol phthalein is shown. The standard of the NaOH solution is determined at the same time by weighing out some of the pure B_2O_3 (No. 3) and treating in the same manner as the solution of the sample.

Boric acid. Vau dam (*J. Pharm. Chim.* [6], VIII., No. 3). Instead of using glycerin in acidimetric titration of B_2O_3, the author finds that mannite is preferable, as it gives a much sharper end-reaction.

Nitrites in water. Robin (*Jour. Pharm. et de Chim.* [6], VII., No. 12). The author claims that the iodine method is superior in sensitiveness to that with metaphenylene diamine. He adds to 50 cc. of the water 2 cc. of a 20 per cent. KI solution, then, after shaking well, 2 cc. glacial acetic. After standing 30 minutes, add starch solution and titrate with N/50 $Na_2S_2O_3$. If the water is colored by organic matter, it may be necessary to add $Al_2(SO_4)_3$ and Na_2CO_3 to clarify it beforehand.

Nitric Acidic in Commercial Nitrates. Ackermann (*Chem. Ztg.*, XXII., 691). When a nitrate is mixed with solution of $FeSO_4$, and but little more NaOH added than will suffice to precipitate the Fe, a distillation of the solution, if not too dilute, affords all the N of the nitrate as NH_3 which may be caught in standard acid, and titrated back.

The proportions recommended are: 1 gm. commencial KNO_3 (to be tested) 30 cc. NaOH solution (Sp. Gr. 1.33) and 40 gms. $FeSO_4$. The volume should be made about 160 cc. Mix in 500 cc. flask, add a pinch of metallic Fe and distil. Thirty minutes should suffice. Before proceeding to titration test the vapors coming over, which should be neutral. A blank test should be made first with the reagents used. A good grade of crude NaOH is preferable to that refined for laboratory purposes. Chlorides and sulphates have no effect, but tartrates interfere as do phosphates. In the case of the latter its influence may be prevented by adding enough $CaCl_2$ to the alkaline solution to convert it to $Ca_3(PO_4)_2$ and then proceeding as above.

Nitric Acid in waters. Bohlig (*Zts. Anal. Chem.*, XXXVII., 498). The method depends on the interaction of HCl from the chlorides of the water with the HNO_3 present, affording Cl, etc., and determination of the Cl by titration with standard K_4FeCy_6 solution.

Evaporate 100 cc. of the water to dryness in an Erlenmeyer flask, cool, add a few cc. conc. H_2SO_4 and at once close the flask with a doubly perforated stopper. Through the perforations pass two tubes which are also in a second stopper fitting another Erlenmeyer flask of corresponding dimensions. Move about the flask containing the H_2SO_4 and water residue until all evolution of gas has ceased, then holding in an inclined position fix the second flask onto the stopper, said second flask containing a known amount of standard K_4Cy_6 solution.

By repeated inversion of the flasks, the K_4FeCy_6 solution is brought into thorough contact with the products of the reaction, when the flasks may be separated, and the excess of K_4FeCy_6 titrated with standard $K_2Mn_2O_8$.

Organic Matter in Water. Differentiation. Woodman (*J. Am. Chem. Soc.*, XX, 497). The idea was suggested by J. Barnes (J. S. C. I., XV., 83). The methods pursued by the author are a little different, and calculated to give more decisive results. It consists in stating the ratio between oxidation by H_2CrO_4 and by $K_2Mn_2O_8$. The details of manipulation are given in extenso. The ratios with peaty waters are above 0.6 with sewage, and sewage-contaminated waters are below that figure. When the ratio is high, the indication is rather in favor of the quality of the water. This aspect of the test merits consideration. At present no positive claim is advanced as to its decisive sufficiency.

Boiler Waters. Rapid analysis. Stillman (*Stevens' Indicator*, Oct., 1898). The scheme was communicated by Prof. Main. Evaporate 500 cc. to dryness in Pt dish. Weight gives *total solids.* Ignite, moisten with water, put into an atmosphere of CO_2 for half an hour, dry and weigh. Loss is "*organic*" *matter* residue *mineral matter.* Extract with successive portions of distilled water, filtering through a small filter, using in all 50 cc. or less. Return paper to the dish, ignite and weigh again. This represents *scale forming* ingredients. Treat this with HCl and filter. Dry, ignite and weigh *insoluble mineral matter.* Precipitate by ammonia. Ignite and weigh Fe_2O_3 and Al_2O_3. In the filtrate precipitate by $(NH_4)_2C_2O_4 = CaO$. Precipitate filtrate with Na_2HPO_4 and excess of NH_4OH, to determine MgO. Acidify filtrate with HCl, and precipitate SO_3 with $BaCl_2$.

[NOTE BY ABS. The author seems to be unaware that alkaline sulphate is an almost invariable impurity in the "C. P." $(NH_4)_2C_2O_4$ and Na_2HPO_4 supplied by dealers, and would cause results as to SO_3 by this scheme, to be quite untrustworthy.]

Krypton. A new element in the atmosphere. Ramsay (*Chem. News.*, LXXVII., 270). Liquid air (750 cc.) was allowed to evaporate slowly, until about 10 cc. remained. In the gas from the residue spectroscopic examination indicated the lines of a new element apparently monatomic, with a probable atomic weight of 80.

ALUMNI AND UNIVERSITY NEWS.

GEOLOGICAL DEPARTMENT.

Several interesting pieces of work are about to be issued by officers of the geological department. Among the unfinished manuscripts left by the late Professor Newberry was one for a monograph of the United States Geological Survey, with the title, "The Later Extinct Floras of North America." It dealt with the fossil plants of the Cretaceous and Tertiary beds of the West and was an important contribution to paleobotany. The entire edition of plates was published years ago, but the descriptive part was in a very incomplete and fragmentary state at the time of the Professor's death. Dr. Hollick has taken the manuscript and plates in hand, has hunted out the type specimens, revised and completed the descriptions

and has brought the volume to a successful issue. It will shortly appear from the Survey, and all old students and friends of Dr. Newberry will be glad to know that one of his most important works is to be placed in general circulation. Dr. Hollick undertook and has completed the task with scarcely less than filial regard for his old friend and teacher.

Dr. Hollick has also issued in recent numbers of the *American Naturalist*, a paper on the connection between the forest growth in New Jersey and the geological formations. Very marked contrasts prevail; deciduous trees predominating in the Highlands on the old crystalline rocks and the glacial drift; evergreens being in great excess on the Tertiary strata of the pine-barrens; while both struggle for the mastery in the Mesozoic belt, which is called the "Zone of Tension." Some interesting relations are likewise developed between the fossil silva and the modern one. Dr. Julien has a paper in press, in the *Journal of the Franklin Institute*, which will shortly appear. It is entitled the "Elements of Strength and Weakness in Building Stones" and reviews this important subject and gives the results of many original observations not hitherto published. Mr. J. D. Irving, Fellow in Geology, has read before the New York Academy of Sciences and expects to issue in the *Annals of the Academy*, a somewhat elaborate paper on the general geology of the northern Black Hills, South Dakota, and will treat at length of their eruptive rocks, both pre-Cambrian and Tertiary, and of the siliceous gold ones. The paper is a thesis for Ph D. and is the result of four months' field-work in the region last summer. Mr. B. F. Hill, Scholar in Geology, passed six weeks in December and January last, in Sonora, Mexico, studying the eruptive rocks in the Barranca coal-field, under the general direction of Mr. E. T. Dumble, lately State Geologist of Texas. A very interesting series of observations and of specimens was gathered which will be elaborated during this year and next for a thesis for Ph.D. Both igneous and metamorphic rocks are present in great development.

Professor Kemp lectured in Philadelphia, February 23d, before the Franklin Institute upon the "Geology of the Titaniferous Magnetites." He described before the American Institute of Mining Engineers, February 22d, the "Zinc-Mines of Franklin Furnace, N. J.," preparatory to an excursion taken by the Institute to visit them two days later. A paper on the "Granites along the North Shore of Long Island Sound" was presented to the Geological Society of America, at the meeting during the Christmas holidays.

The department has received a fine suite of meteorites from Mr. Geo. F. Kunz; a suite of crystalline rocks from Wyoming from Professor W. C. Knight, of the Wyoming State University, at Laramie; and a valuable series of ores and rocks from the Trail Creek region of British Columbia, from S. S. Fowler, '84. A series of Pleistocene fossil plants from Ontario has been kindly sent by Professor Coleman of Toronto. The thanks of the department are expressed to all these friends for the gifts.

J. F. K.

SCHOOL OF ARCHITECTURE.

The circulars have just been issued for the fifth McKim Fellowship competition. There will this year be two Fellowships awarded, of $1,000 each, instead of a single Fellowship of double that sum, and the winners

will, as usual, be required to spend at least one year in travel and study in Europe, in accordance with a programme to be approved by the President and the Professor of Architecture. The subject announced for the competition, which is open to all graduates of the Department of Architecture, not over thirty years of age, is a School and Museum of Architecture, and the preliminary sketches will be made in the department rooms in Havemeyer Hall on Saturday, April 1st; the finished drawings to be handed in five weeks later.

Of the recent holders of the Travelling Fellowships in Architecture of this school, Mr. J. A. Pope, Jr., winner of the McKim and Roman Scholarships of 1895 is in Paris, completing his studies for the French government diploma in architecture: Mr. H. A. Jacobs, McKim Fellow in 1897, is also in the Ecole des Beaux Arts with Mr. W. C. Ayres, who won the Columbia Fellowship last year; Mr. W. S. Covell, Columbia Fellow of 1896, has since his return from Rome established himself in the practice of architecture in partnership with his classmate, Mr. H. A. Smith, '93.

Mr. H. F. Hombostel, '91, Assistant in Design, in charge of the fourth class, is at this writing in California, on a brief visit in connection with the Phoebe Hearst competition of the new buildings of the Leland Stanford Jr. University, his place being taken meanwhile by Mr. A. Raymond, also of the class of '91. In the great international competition inaugurated by Mrs. Hearst's generosity for the extraordinary group of buildings projected for that university, and in which prominent architects of both the Old and New Worlds participated. Messrs. Havells and Hombostel associated, were among the premiated competitors entitled to take part in the second and final competition—a very distinguished honor, and a signal proof of merit and ability. Mr. Hombostel will be back in a few days to take up, in connection with Professor Hamlin, the supervision of the fourth-year thesis work.

The subjects for the Theses, as finally announced, are as follows: A Group of University Buildings; An Entertainment Hall; A Clubhouse in a Large City; A State Capital; A Hotel in the Mountains; A National Soldiers' and Sailors' Monument; A Protestant Cathedral in the Gothic Style; A School of Fine Arts; A Large City Mansion; A Military School; A City Hall and County Building; A Bathing Establishment; A School of Industrial Design.

All these in the elective course in Design. In the elective course in Engineering and Construction two theses will be submitted, one a Railway Terminus, the other a High Masonry Dam.

The new scheme by which the instruction in Building Materials, and Specifications is concentrated in the third year is working well, in connection with the new institution of a whole day of practice on alternate Thursdays, under Mr. Warren's personal direction. The remaining Thursdays are similarly taken up by a whole day's practice on problems in Architectural Engineering under Mr. Snelling; and these days of practice have been found extremely profitable.

The second and third classes are now busy in the afternoon with research or seminar work on history of Gothic architecture. The fine equipment, both of the Department Library and of the Avery Library, is again demonstrating its value, and the draughting room connected with the Avery Library is daily thronged with our students, who are privileged

there to use the valuable resources of the Avery Library in the freest possible manner under Mr. Patridge's supervision, while Mr. Smith is left free to attend to his duties in the Avery Library proper. The experience of last year's research proved that this privilege of free use of the Avery books in the adjoining draughting room resulted in no injury to or improper treatment of the books, while it more than doubled the usefulness of the library to the students. The room has also been used this year by Professor Ware with the Fourth Class for the weekly Fourth Year essays on advanced historical research, making the Avery books available for illustration of the papers read. Mr. Avery's munificence is bearing richer fruit every year.

A volunteer modelling class has been meeting Saturday mornings under the instruction of Mr. E. R. Smith of the Avery Library, who is an accomplished sculptor. The work is done in a room adjoining the Museum of Building Construction over the School of Architecture, and the results have been most encouraging.

Professor Hamlin was called to Philadelphia on March 13th to assist in the award of the John Stewardson Memorial Scholarship in Architecture. He has recently served as consulting architect for the competition for the American church at Charlottenberg (Berlin) Prussia; and is to judge in May the competitive drawings for the proposed Y. M. C. A. building at New Haven, Conn.

A. D. F. H.

ELECTRICAL ENGINEERING DEPARTMENT.

Owing to Professor Crocker's absence during this Academic year, Professor W. A. Anthony is delivering the lectures of the fourth year in Electric Power, Electro-chemistry and the Management of Electrical Plants. He is also giving the lectures to the third year Civil and Mining Engineers in Electrical Engineering.

The members of the Senior class in Electrical Engineering, accompanied by Mr. G. F. Sever and Mr. W. H. Freedman, visited the works of the General Electrtc Company, at Schenectady, N. Y., on February 9th and 10th.

These two days were spent in going through the factories and carefully noting the construction of the numerous features of electrical and mechanical apparatus. On February 11th the party went to Mechanicsville, N. Y., in order to inspect the water power station recently installed at that place on the Hudson river. The energy transformed at this place is transmitted to Schenectady, 20 miles distant, for use at the works of the General Electric Company and about the City. The pressure used on the transmission lines is 12,000 volts. After the inspection at this station the party returned to New York via Albany.

Every facility was afforded to the members of the party by the General Electric Company for obtaining information as to the construction and methods employed in the manufacture of electrical machinery.

This was a most instructive trip and it would be desirable to establish it as a regular feature of the Senior year.

Earlier in the fall the Senior class in Electrical Engineering, paid a visit to the works of the Crocker-Wheeler Electric Company at Ampere, N. J., in order to inspect the methods of dynamo and motor construction.

The Alternating Current Laboratory work has been greatly developed during the last year, this being possible from the fact that the facilities for conducting the work have been extended and the work has been conducted in a systematic manner. There is yet wanting in the machine laboratories of this Department, much apparatus for the proper conduct of the work. A modern alternating current dynamo, motors of recent type, transformers and measuring instruments are essential requirements which the Department greatly needs. Through the generosity of friends it is hoped that these will be supplied.

The Beacon Lamp Company has recently presented to the Department a large collection of incandescent lamp material, in order to illustrate the construction of all the parts of the lamp.

One hundred and thirty-five students are now pursuing the course in Electrical Engineering. G. F. SEVER.

DEPARTMENT OF METALLURGY.

The following notes of interest are to be recorded, and for convenience are presented under the heads of

1. Departmental Library.
2. Furnace Room Equipment.
3. Special courses, post-graduate, thesis, and other investigations pursued in furnace room and laboratory.
4. Lectures.
5. Collection.
6. Donations to the Department.

(1.) DEPARTMENTAL LIBRARY. The gift of nearly a thousand standard books and periodicals recently presented by Professor Thomas Egleston has been recorded and systematically placed in the cases. These works, together with those originally set aside from the main library, now constitute a collection of works on metallurgy and allied subjects which may be considered as one of the best working metallurgical libraries extant.

The books are properly catalogued and arranged in one of the rooms of the department with tables for the use and comfort of the students.

Weekly and monthly publications covering American, English, German and French practice are on file and afford excellent means of keeping the literature of the subject fully up to date.

Students attending the lectures on metallurgy may be permitted to take out books over night, to be returned on the following morning; in this way the value of the library for reference is in no way impaired.

(2.) FURNACE ROOM EQUIPMENT.—The gift of a separate fund from an anonymous friend has enabled the department to make a fair start with the equipment of the furnace-room, and several furnaces and primary pieces of apparatus have been purchased and put in place.

The following furnaces are now installed and in use:

A. A large down-draft crucible furnace which will contain a No. 40 graphite crucible of a capacity of 80 pounds of iron or steel, and a specially designed crane to handle the large crucible.

This furnace has given us excellent results as to high temperature attained and ease of control.

B. A large oven furnace with a hearth of 18″ x 24″ in area, suitably connected by overhead pipe to the chimney flue.

This excellent furnace affords ready means for pursuing investigation on the heat treatment of metals and on roasting ores in small amounts.

This furnace has proven of good value for student and department use.

C. A set of leaching barrels and tubs has been arranged in terraced framework for experimental work on leaching gold and silver ores by the wet processes, such as the Russell or cyanide processes. This small experimental plant is adapted for copper ores or other material to be treated by wet methods.

D. A work bench with ordinary tools for repairs and construction of simple apparatus has been set in place and furnishes the department with ready means for setting up new arrangement of apparatus without delay.

E. Necessary accessions to the microscope for the examination of metals, including a photo-micrographic outfit.

F. A drill for taking metal samples.

G. The electric furnace is now in the hands of the designer.

H. The gas-fired regenerative furnace, operating with natural draft, fully described in the SCHOOL OF MINES QUARTERLY, Vol. XV., No. 2, p. 138, January, 1894, has been set in place and is ready for special work.

I. The gas-fired furnace procurred for the Committee on Tests by Mr. Henning is in place and has proven of value to the department, as it will heat up, with fair uniformity of temperature, a bar of metal 28 inches long.

J. The department now has two Le Chatelier thermo-electric pyrometers installed in the furnace room, with necessary switches, pole changers, and connections.

K. Work of special value is now being carried on in this furnace room by students in post graduate and undergraduate courses, as well as by the department, and this branch of the department will doubtless prove of growing attraction for special and graduate students.

The present installation, while excellent as far as it goes, is inadequate for the demands which may be reasonably expected within a year or two.

(3.) SPECIAL INVESTIGATIONS.—The following investigations are now being pursued in the department furnace room and laboratory: "The Relative Desulphurizing Power of Lime and Magnesia," "The Effect of Exposure to Different High Temperatures and for Different Lengths of Time, on the Micro-Structure and the Tensile Properties of Half-Hard Steel," "The Elimination of Arsenic in Roasting," "The Condition of Arsenic, Antimony and Bismuth, whether as oxide or metal in Overpoled Copper, "The Relation between the Electrical Conductivity, the Vicosity and the Composition of Silicates."

(4.) LECTURES.—During January, 1899, Professor Howe delivered the shortened course on iron and steel for the students in the School of Mines and in the School of Chemistry. The special feature of the short course is to provide the students with a knowledge of the subject as pertains mainly to those physical properties of iron and steel which are of such great value to the engineer from a constructional standpoint. A brief outline of the course is:

Course 2. THE METALLURGY OF STEEL AND IRON—The properties of steel, cast-iron, and wrought iron, as influenced by composition and by thermal and mechanical treatment, together with a brief account of the chief process by which they are made. 3 hours a week during January. Professor Howe.

Required of third-year students in the Schools of Mines and Chemistry.

The new long course on iron and steel will be delivered by Professor Howe during the second term to the students in the courses of Civil, Electrical, and Mechanical Engineering. Briefly outlined, the course consists of

Course 3. THE METALLURGY OF IRON AND STEEL—Ores: Classification and constitution of iron and steel; the blast furnace; composition and properties of cast iron; composition of wrought iron and steel, and the influence of thermal and mechanical treatment, puddling; the Bessemer, open-hearth and crucible processes, forging and rolling; casting cast-iron and steel; and the minor processes of steel and iron making. 3 hours lectures a week, second half-year. Professor Howe.

Required of third-year students in the course of Metallurgy and Mechanical Engineering, and of fourth-year students in the courses of Civil Engineering and Electrical Engineering. Students in the course of Metallurgy have an additional hour per week.

METALLURGICAL EXCURSION.—On Saturday, March 25th, the students of the fourth class in the Schools of Mines and Chemistry, under charge of Dr. Struthers, visited the large Smelting and Refining Plant of Guggenheim Bros., near Perth Amboy, N. J. Through the courtesy extended by Superintendents L. G. Eakins and H. Matthewson, the processes for smelting and refining lead, copper, silver and gold were thrown open for inspection and study.

(5). THE COLLECTION. The large amount of accumulated material is now being overhauled carefully, and those specimens of value are afforded a space in the exhibit cases on the floor of the main room of the department. It is the idea of the department to make this exhibit collection mainly instructive in character rather than attractive in appearance.

The use of many of these specimens for lecture illustration has proven of great aid in instruction work.

During the past summer several specimens of iron and steel showed a tendency to rust on polished and freshly fractured surfaces. To overcome this difficulty, one of the large cases has been made practically air-tight in construction. Air is admitted through metal pipes to the bottoms of four calcium chloride jars, one jar in each corner of the case. These jars will dry the air which is drawn in by contraction due to cooling. Open jars of comparatively large surface will be placed on the shelves so as to dry the air thoroughly, which will enter when the case door has to be opened.

The department has secured, by purchase and gift, considerable stock material for use in the laboratory courses. Suites of steels of required varying composition, copper ores and mattes, rich and poor in silver and gold, ingot copper, acid and basic refractory materials, etc.

(6) DONATIONS. The more important gifts of recent date to the Department are outlined below, and we take this opportunity of expressing publicly our appreciation and thanks to the kind donors:

Samples of lead and copper matte from Argentine, Kas., from W. A. Smith, Jr.

A suite of fifty lantern slides illustrating the physical constitution of steels and irons, from Mr. J. E. Stead, of Middlesborough, Eng.

A suite of specimens illustrating the heat treatment of iron and steel, from Mr. J. A. Brinnel, of Fagersta, Sweden.

A suite illustrating the reduction of aluminum, from the Pittsburg Reduction Company.

A suite of a large number of nickel and chromium steel specimens with analyses, especially selected for lecture illustration and for investigation work, from W. B. Kunhardt, E.M., of the Carpenter Steel Company.

A number of Ferro alloys, from O. M. Hartzell Company, Pittsburg, Penn.

Crystals of iron, from Mr. P. Kreuzpointner.

A large suite of special steels with analyses, from Mr. R. E. Jennings, Jersey City, N. J.

A large number of samples of pig iron and slags of the Illinois Steel Company, from B. Stoughten.

An iron casting with charred lace for a pattern, from A. E. Outerbridge.

A large drawing of the Taylor Gas Pruducer, from R. D. Wood & Co., Philadelphia.

A wire-drawing machine, from the Roebling Co., of Trenton, N. J.

Micro-sections of steet, from F. Osmond, Paris.

A number of Ferro-alloys with Mangenase, Silicon, Tungsten, Chromium, etc , from George G. Blackwell Sons & Co., Liverpool, England.

Cast-iron samples, from the Columbus Machine Co., Columbus, Ohio.

Open Hearth Furnace Linings, Mr. Talbot, Pencoyd, Pa.

J. STRUTHERS.

BOOK REVIEWS.

A Hand-Book of Metallurgy. By DR. CARL SCHNABEL. Translated by HENRY LOUIS. Two volumes. Vol. I. : Copper, lead, silver, gold. Vol. II. : Zinc, cadmium, mercury, bismuth, tin, antimony, arsenic, nickel, cobalt, platinum, aluminum. New York, The Macmillan Company. Illustrated. Medium 8vo. Total pages, 1608. Price, $10.00.

The author states in the preface that, while many exhaustive works have appeared on the metallurgy of individual metals, the few books on general metallurgy were arranged as text-books and made no pretence of thoroughness of detail or treatment. With these facts in mind the present work was compiled with the stated object of giving a complete account of the metallurgical treatment of every one of the metals ordinarily employed, together with recent improvements in the art, stating the underlying scientific principles and illustrating by actual practice.

This object is highly commendable, but the statement is rather misleading, as iron and steel have been entirely omitted and no mention made of the omission or of a subsequent volume upon this all important branch

of metallurgy. This fact should have been stated plainly by the author in the preface and by the publishers in the advertisements.

Dr. Percy's historic work was selected as the basis, and on this are grouped many facts from the works of modern writers; notably, Hofman on lead, Peters on copper, Egleston on gold and silver, and Borchers on electro-metallurgy. The work is very exhaustive in character as the grand total of 1,608 pages indicates, but unfortunately the exhaustion is not limited to the subject-matter of the book and oft-times extends to the reader, as much of the material is vague and unnecessarily verbose. The work lacks that clearness of description, lucidity of arrangement and conciseness of statement so needful in the treatment of a large subject and so appreciated by American readers with whom time is an object.

It is to be regretted that much ancient material is perpetuated in excruciating detail, particularly as it is so interwoven with modern practice that the general reader is left in doubt as to what *is* in use at the present time. As an instance of this, under the chapter on silver: Barrel amalgamation is quoted as now in use in the Pelican Mill, Georgetown, Colo., while, as a matter of fact, it was abandoned there twenty years ago. Another instance under the chapter on zinc: The furnace used in the old English process—that rare bird of antiquity—shows forth resplendent in full-detailed illustration. As to this furnace, Dr. Percy, in 1869, failed to find even the ruins of its foundation.

The large amount of material collected in these two volumes contains much of value to the specialist, but it is too encyclopedic in character to be of any marked assistance to the general reader. Its main value is for reference in a scientific or technical library.

A few minor errors, such as the location of Boston in Vermont (Vol. I., page 115), and Orford in New Jersey (Vol. II., page 104), may be overlooked in a work of this large size.

The criticism of this work may be considered harsh, but the eminent position occupied by Dr. Schnabel leads one to expect the highest standard of work and to be disappointed if it is not attained. J. S.

Minerals in Rock Sections. By Lea McIlvaine Luquer, C.E., Ph.D. New York, D. Van Nostrand Company. 1898.

The application of the microscope to the study of rocks has not only developed a branch of geology second to no other in purely scientific importance, but it has also furnished new methods for the study of ore deposits, building stones and other economic products. To the mining and civil engineer, therefore, as well as to the geologist, a knowledge of at least the elements of petrology cannot but be of the greatest service.

The subject, however, is not a simple one, and so much has to be crowded into the courses of our scientific and technical schools that the standard text-books of petrology are much too extended to be available.

It is to meet this difficulty, in part, that the present book has been written, its aim being to do for minerals what was so well done for rocks in Harker's "Petrology for Students."

The book opens with a condensed discussion of optical mineralogy, as clear as is consistent with such very narrow limits. Here, as elsewhere, the student is referred to standard works in which the subjects are discussed in detail. Some amplification is also afforded by the footnotes,

which in several instances might to advantage be incorporated with the main text.

The second chapter describes the essential features of the petrographic microscope, while in the third the common methods of determining minerals in thin sections are presented. Form, color, relief, structure, etc., as seen in ordinary light, are first considered, and then follows a simple statement of the application of parallel and convergent polarized light. The accompanying illustrations, drawn by the author from sections, are excellent, and, though they may lack the strict accuracy of microphotographs, are certainly more instructive to the beginner. The sketches of interference figures are less commendable. This, the leading chapter of the book, is very satisfactory, although the author has, perhaps erred on the side of condensation.

In Chapter IV. the common rock-making minerals are given in the usual order. Their distinguishing properties are well summarized, and heavy type renders prominent the more important data.

The use here made of the word "Differentiation," in a sense totally distinct from that in which it is so commonly employed in petrology, is decidedly infelicitous.

Chapter V. is devoted to methods of preparing sections. Though good in itself, it occupies a disproportionate amount of space.

An outline of mechanical and chemical tests closes the main part of the book, while the appendix gives, among other matter, a tabular scheme for the microscopic determination of the commonest species. This is analogous to Loewinson-Lessing's "Synoptical table," but accentuates relief instead of color as a distinguishing feaure.

The treatment is eminently practical throughout, and the book is well calculated to serve as an introduction to the study of petrology. To the technical student it furnishes, in convenient form, the data needed in his profession; while in many cases it will doubtless stimulate an interest that will lead to the study of more advanced works.

The author is to be congratulated upon having accomplished the difficult task of producing so useful an epitome of a large and complex subject. C. H. S., JR.

Physical Chemistry for Beginners. By VAN DEVENTER and VAN'T HOFF. Translated by B. B. BOLTWOOD. New York, Wiley & Sons. 12mo. 154 pages. $1.50.

This text-book is based on the lectures of Van't Hoff, and translated from the German edition of Ch. M. van Deventer by B. B. Boltwood, Ph.D., of Yale University. The chapters take up the following subjects:

I. Definitions, etc.
II. Fundamental Laws of Composition.
III. The Properties of Gases.
IV. Thermochemistry.
V. Solutions.
VI. Phenomena of Light.
VII. The Periodic System.

The book treats of much which is the theoretical side of general chemistry rather than purely physical chemistry, and is for this reason better adapted for an elementary text-book than many of the works on physical chemistry.

In this way it will serve as an introduction to the mathematical side of Physical Chemistry by giving the student an insight into the practical bearing of the laws of gases, thermochemistry, solutions, etc., before he attempts their experimental verification or mathematical deduction.

The work is the expression in as simple terms as possible of the fundamental principles of theoretical chemistry; briefly stated, but by a mind which grasps the entire field, and particularly the connection of one law with another, it is a most excellent book, and will prove useful to many besides students, who, though experienced in other lines, are beginners in physical chemistry. E. H. M.

The Metallurgy of Lead and the Desilverization of Base Bullion. By H. O. Hofman. First edition, rewritten and enlarged. New York, Scientific Publishing Co. 1899.

The previous editions of this work have become so well known that a detailed description of its contents is hardly called for. In general the author has discussed the subject under three parts: Part I—Introduction, including history, statistics, properties of lead and its compounds, ores, distribution, receiving, sampling and purchasing ores, fluxes and fuels. Part II—The metallurgical treatment of lead ores discussed under the heads of classification of methods, smelting in the reverberatory furnace, smelting in the ore-hearth, smelting in the blast furnace, general smelting operations and furnace products. Part III—Desilverization of base bullion, as accomplished by the Pattinsonage and the Parkes processes, with a discussion of cupellation.

The metallurgy of lead progresses so rapidly in its development that a few years' time shows a marked change in the details of the smelting of its ores, and while the chemical principles underlying the process remain fixed, details of manipulation are constantly varying to meet new requirements of changing composition, amounts of ores to be treated, variation of product, etc. The advancement during the last few years has been more along the mechanical side of the subject, and to keep in pace with the times the author has brought out the present fifth edition. Considerable new material has been added from the monographs which appear annually in the "Mineral Industry of the United States."

The most important change in the book is the chapter on the roasting of lead ores, which has been rewritten and enlarged.

The number of pages has been increased from 414 in the first edition to 559 in the present one. Many new illustrations have been added and the typography is of a better order and arrangement than in the former editions.

The book in its present edition is an admirable compilation of the subject and reflects great credit on its author for the painstaking care and untiring labor he has bestowed upon the work. J. S.

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THE SCHOOL OF MINES QUARTERLY.

A

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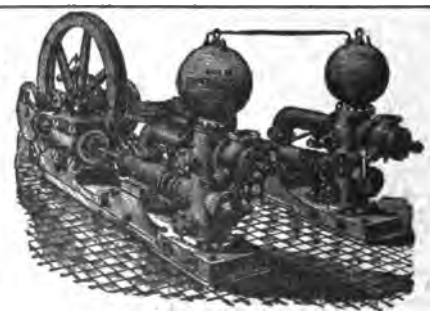

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THE

SCHOOL OF MINES QUARTERLY.

VOL. XX. JULY, 1899. No. 4.

A BRIEF REVIEW OF THE TITANIFEROUS MAGNETITES.

BY J. F. KEMP.

Introduction.
North America:
Canada, Quebec.
Ontario.
Colorado.
Minnesota.
New Jersey.
New York.
North Carolina.
Rhode Island.
Virginia.
Wyoming.
South America:
Brazil.
Europe:
Finland.
Norway.
Russia.
Sweden.
Australasia:
New Zealand.

INTRODUCTION.

The known deposits of magnetic iron ore may be conveniently classified into two groups on the basis of chemical composition: the titaniferous and the non-titaniferous. This grouping not only corresponds to the chemical composition, but also to the geological relations and to the present utilization and non-utilization.

Among the magnetic ores the non-titaniferous are to-day the only ones mined and smelted and even their productiveness has decreased notably in recent years, because of the great influx of cheap and easily reduced hematites from Lake Superior. The Cornwall banks in Pennsylvania are almost the only large American magnetite mines now in active operation. The geological relations of the non-titaniferous ores are variable, and, in one place

and another, they have resulted from very different originals and by strongly contrasted processes, but if titaniferous iron sands are omitted, the massive titaniferous ore-bodies may be said to be closely allied in character and origin wherever they have been studied.

Aside from one or two exceptions, such as the Brazilian localities and the ores at Alnö in Sweden, they are associated so far as known with rocks of the gabbro family and furnish a distinct type of ore-body, that is singularly uniform the world over. They constitute in most cases large irregular masses in the midst of intrusions of igneous rock and seem to have been produced by the segregation of fairly pure titaniferous iron oxide either before or during the process of cooling and consolidation. In less common instances the entire mass of a dike or stock is so enriched with the iron-bearing mineral as practically to be considered an ore. Although the ores are not at present the objects of active mining, yet the quantity is so large, and the iron afforded by them has such peculiar advantages of its own, doubtless owing to certain chemical elements generally present in the ore, that it seems improbable that they will long go without utilization. Some metallurgical demand is quite certain to develop, which will make them extremely desirable.

The wall-rocks, referred to as belonging to the gabbro family, embrace a series beginning with nearly pure aggregates of labradorite, known as labradorite-rock or prevailingly now in America as anorthosite, and continuing with true gabbros, norites, diabases and peridotites. To these must be added the Brazilian nepheline-plagioclase rocks and the nepheline-syenites at Alnö, Sweden. When enriched with the ore in greater or less degree, each of these affords variations from the main type, which have sometimes received special names.

In not all the known American occurrences have the wall-rocks been microscopically or very accurately determined, and it is possible that in some instances dynamic metamorphism has changed original massive intrusions into more or less obscure gneisses. Abundant experience, already recorded, indicates that the gabbro group of rocks is particularly sensitive to metamorphic processes. The pyroxene changes to hornblende with great facility, so that dioritic gneisses often result. It is also fair to state that so far as known the titaniferous ores are in all cases in North America in

rocks of pre-Cambrian Age, and, therefore, that they have passed through metamorphic changes of greater or less intensity in nearly every instance.

In their mineralogical composition the ores involve both ilmenite, FeO, TiO_2 (FeO 46.75, TiO_2 53.25, *i. e.*, Fe 36.36), and titaniferous magnetite, whose chemical composition cannot readily be expressed by a formula. The latter may be strongly magnetic and may be even natural lode-stone while high in TiO_2. The ore minerals are mixed with varying amounts of pyroxene, brown hornblende, hypersthene, enstatite, olivine, spinel, garnet, plagioclase, and biotite, and a quite extended experience with thin sections has convinced the writer that a sample may appear black and rich to the eye, which is really in large part composed of the above silicates and spinel. The strong magnetism of some titaniferous magnetites shows the improbability of removing the titanium by magnetic concentration. In most cases, while the iron is increased in the concentrates by the elimination of the ferro-magnesian silicates, the titanium is also increased. The removal of the titanium by the selection of slags of appropriate composition is far more feasible.

In their chemical composition the ores are characteristic and marked. As a rule, but not invariably, phosphorus and sulphur are notably low or entirely absent. Vanadium, chromium, nickel and cobalt are almost always present, and they may together amount to several per cent. Magnesia and alumina are often far in excess of what would be required for silicates and then they are doubtless combined with more or less iron in spinels. Lime is of course involved in the presence of the pyroxenes and related minerals. Manganese is often but not invariably at hand; zinc has been recorded in several instances, and carbon in an uncombined state has been detected in ore from the Adirondacks. These topics are not taken up in further detail here, because, in connection with a paper on the "Titaniferous Iron Ores of the Adirondacks"* the writer has discussed the composition and methods of origin of these ores at length, and the latter topic has been previously taken up by J. H. L. Vogt† in a series of valuable and suggestive contributions relating to various types of iron ores. It is

* Nineteenth Annual Report of the Director of the U. S. Geological Survey, Part III., pp. 377–422.

† Dannelse Jernmalmforekomster, Norwegian Geological Survey, Kristiania, 1892. Résumé in German, p. 145. Zeitschrift für praktische Geologie, Jan., 1893, pp. 69.

the purpose in the present paper to review and summarize what is known of the occurrences of the titaniferous magnetites in different parts of the world and to make available in a brief compass what is scattered through much literature. The localities will be taken up in alphabetical order under the continents, beginning with North America.

The long series of analyses will illustrate the ranges in composition, and the citations will place the reader in command of the literature.

Canada.—For many years past it has been well understood that large deposits of titaniferous magnetite occur in Quebec and Ontario. The investigations of the late Dr. T. Sterry Hunt long ago led to the important generalization that they are characteristic of the labradorite rocks of the Norian or Upper Laurentian system of the Canadian geologists. The recent work of Professor F. D. Adams has outlined the distribution of the Norian rocks much more accurately than had been previously done, and as the presence of the titaniferous ores is conditioned by the occurrence of the anorthosites and more basic gabbros of this series, it follows that the geographical distribution of the ores has also been indicated.

Adams has described two principal areas, the Saguenay, around the headwaters of the river of the same name and the Morin, north of Montreal. In addition to these there are smaller ones along the north shore of the St. Lawrence river and gulf. In the Saguenay area, and on the Saguenay river, between Chicoutimi and Lake St. John, huge masses of ore occur in the eruptive rocks. On the north bank of the river there are groups of hills entirely composed of it.* The ore occurs principally in three bands, the most easterly of which is about 75 yards wide. The relations are similar to those of the ore near Lake Sandford, in the Adirondacks, as later described. In the Morin area north of Montreal, near St.

*On the Geology of the Norian Labradorite Rocks, see F. D. Adams, Ueber das Norian oder Ober-Laurentian von Canada, Neues Jahrbuch, Beilage Band VIII., 419–499, Taf. xix. An English translation by N. J. Giroux, with a map, appears in the *Canadian Record of Science*, 1894, 169–198; January, 1895, 1–28; July, 1895, 1–28. The papers contain a full bibliography. but they make slight reference to the ores.

F. D. Adams, On the Igneous Origin of Certain Ores. Read before the General Mining Association of the Province of Quebec, Montreal, January 12, 1894. Brief notes of the Morin and Saguenay ores are given, and a picture of the hills of ore near Lake St. John.

Hypolite and St. Julienne, masses of considerable size are known and are regarded by Adams as a special local enrichment of the gabbro with one of its constituent minerals. No one of these has yet been utilized. Dr. Harrington has published a partial analysis of the St. Julienne ore (I.) as follows * and has given with it one from St. Jerome (II.):

	I.	II.
Fe	38.37	24.65
TiO_2	33.67	32.36

The mass that has received most serious attention as regards smelting is at Bay St. Paul about fifty-four miles below Quebec on the St. Lawrence river. It is known to be ninety feet thick and to extend for several hundred yards. R. W. Ells† states that it was discovered in 1666, by Sieur de la Tasserie and that explorations were carried on the following year by Colbert's orders—under the sanction of the King of France. An extensive attempt was made to smelt the ore in 1873, and two blast furnaces were erected in November of that year, by the Canadian Titanic Iron Company. Adams states that about 80,000 pounds sterling were lost in the venture, and in 1880, it was discontinued. The analyses subsequently given will show percentages of titanic acid reaching nearly to 50, which considered merely as gangue, would be clearly prohibitive, aside from any chemical reactions involved. The ore occurs in an area of Norian rocks called by Adams the St. Urbain from a neighboring town.‡ An analysis by T. S. Hunt gave the results in I., one by Frederick Penny those in II. Both are taken from B. J. Harrington's paper as cited below. No. II. is stated to contain no Mn, P or S.

	I.	II.
Fe_2O_3	10.42	20.35
FeO	37.	29.57
Al_2O_3		4.00
CaO		1.00
MgO	3.60	3.17
TiO_2	48.60	40.
SiO_2		1.91
	99.68	100.
Fe	36.12	37.25

* B. J. Harrington, Geol. Survey of Canada, 1873–74, 227.

† R. W. Ells—Report on the Mineral Resources of the Province of Quebec. Geological and Natural History Survey of Canada. New Series. 1888–89. 14k.

‡ A short historical sketch of the attempts to utilize this ore in the bloomaries will be found in the Journal of the British Iron and Steel Institute, 1871, II., 130. A fuller account by Dr. B. J. Harrington is given in the Geological Survey of Canada, 1873–74, 227, 249.

Further down the St. Lawrence and still on the north bank other huge masses are known on the Rapid River, near its entrance into the Bay of the Seven Islands. T. S. Hunt* has described them as having a breadth on the stream of 500 yards from east to west, and as extending some distance north and south. The ore is coarsely crystalline, black and brilliant, and contains embedded grains of feldspar and probably pyroxene. It is quite magnetic. Analyses are given below, but it may be stated here that Dr. Hunt found 57% to be separable with a magnet, and 43% to be inert. The former yielded the results in I., the latter those in II.

	I.	II.
FeO	49.77	39.75
TiO_2	34.30	51.14
Insoluble,	6.35	8.30
Total,	90.42	99.19
Fe	38.70	28.78

Reserving the titaniferous iron sands of the lower St. Lawrence for a subsequent paragraph, the ores on the south side of the river in the eastern townships may be next noted. The townships of Brome and Sutton contain both titaniferous and non-titaniferous varieties, but the latter will probably be found to occur in more or less metamorphosed gabbros or rocks related to them, although the wall-rock is as yet merely described as metamorphic. Dr. Harrington has made the following determinations :‡

	Fe.	TiO_2.
Sutton, Lot 9, Range 11,	40.87	27.20
" Lot 8, Range 9,	39.14	29.86
Brome, Lot 1, Range 3,	41.46	24.16

The townships are situated just north of Vermont, and in the general region of the serpentine belt that yields the well-known asbestos. The ores were described in 1847, as occurring in the vicinity of two dolomite belts, and as occupying the two sides of a ridge, which traverses Brome and Sutton townships. All are more or less titaniferous, and some are strongly so.* The percentages in iron are often very low.

* T. S. Hunt, Report on Iron and Iron Ores, Geological Survey of Canada, 1867–69, 260.

† Geological Survey of Canada, 1873–74, 228.

‡ T. S. Hunt, Geological Survey of Canada, 1847, 59. See also R. W. Ells, quoting above report, Idem, 1888–89, IV., 16 K.

Dr. Hunt has also described a great mass of titaniferous ore which occurs in serpentine on the Colway River four miles north of the Chaudière. The thickness is stated to be forty-five feet. Dr. Hunt made some experiments in magnetic concentration, with the view of eliminating the titanium. Two-thirds proved magnetic and one-third regarded as ilmenite was inert. The latter contained TiO_2 48.60, Fe_2O_3 40.70.

Titaniferous magnetites are also known in Ontario, in the eastern counties, and in the same region are others without titanium. Dr. E. J. Chapman has described both.* Several ranges run through the counties of Victoria, Haliburton, Peterboro and Hastings. In the Pine lake location, on lot 35 of the fourth concession of Glamorgan, an enormous deposit of black magnetic ore, of granular texture rises abruptly in an immense ledge, or succession of ledges to a height of from eighty to one hundred feet above the general level of the ground. "It is exposed in an easterly and westerly direction over a length of at least 1,800 feet, with an average width of about 140 feet. Actual measurements vary from seventy feet in some places to 198 in others." An analysis of a sample taken from different parts of the deposit yielded Dr. Chapman the results given in column I., below, but attention may be also directed to the analyses by F. J. Pope, that follow:

	I. Pine Lake.	II. Minden.	III. Tudor.	IV. Mud Lake.
Fe_3O_4	71.87	71.22	83.36	69.77
TiO_2	13.30	25.51	8.08	9.80
Al_2O_3	——	——	——	5.65
SiO_2	——	——	——	7.10
$CaCO_3$	0.86	——	——	——
H_2O	——	——	——	2.45
Rock	15.28	5.13	9.31	——
MgO	——	——	——	4.50
Fe	52.04	51.56	60.36	50.23
P.	tr.	tr.	tr.	0.85
S.	0.06	0.43	0.08	1.520
Sp. Gr.	4.437	4.336	4 480	

I. E. J. Chapman, see citations below. Ore dried at 212° F. Another sample gave TiO_2 12.01.

II. Do. Lot 11, concession 1 of this town.

III. Do. Township of Tudor, County of North Hastings, lots 55–57 of the Free Grant District, Louise mine.

IV. T. S. Hunt, Geol. of Canada, 1867–69, 245, Mud Lake, Rideau Canal, township of South Crosby.

*E. J. Chapman—On some Iron Ores of Central Ontario. Trans. Royal Soc. Canada, 1885–9. On some Deposits of Titaniferous Iron Ore in the Counties of Haliburton and Hastings, Ont., Idem, 1884, 159.

The other ores of this range are quite free from titanium, but still further north, in the township of Minden, the titaniferous magnetites occur again. A black granular variety, strongly magnetic, from lot 11, concession 1 of this town, yielded the results under II.

"In the township of Tudor, in North Hastings (lots 55–57 of the Free Grant District), a large deposit of titaniferous magnetite, very similar in character to the 'Pine Lake ore,' is known as the Louise mine. It is an 'immense stock or irregular mass, the principal axis of which extends in a direction a little north of east. It forms a steep slope or ridge, rising above the general surface of the ground to an average level of nearly one hundred feet.' It varies from 60 to 160 feet, or perhaps more, in width and exceeds 1400 feet in length. It is granular, black and strongly magnetic and has the composition shown under III."

Dr. Chapman remarks that if the TiO_2 is expressed as Ti_2O_3 the excess of the totals in the above analyses above 100, largely disappears. The excess was general in the analyses when computed on the basis of TiO_2.

A large deposit of titaniferous ore has long been known on an island in Mud lake on the Rideau canal, in the township of South Crosby.* Dr. Hunt states that the ore contains chlorite and pyrites. An analysis is given under IV.

The titaniferous ores of eastern Ontario have been carefully studied both chemically and geologically by F. J. Pope, and with the latter part of his work the writer has been personally familiar. The results have just been issued by the American Institute of Mining Engineers. The following analyses indicate in considerable detail the composition of the ores.

When microscopically determined the wall-rocks were found to be the following. The Chaffey ore is near the margin of a large and somewhat gneissoid mass of gabbro—which consists of plagioclase, augite, diallage and original hornblende. The dark silicates are in excess. The Pine Lake ore occurs in an elongated lense of gabbro of varying width, which penetrates the gneisses and schists. Near the ore the feldspar fails and the rock becomes a pyroxenite, being chiefly reddish, brown augite, with some grains of amphibole, the product of uralitization. Magnetite and a little pyrites are the only other minerals present. The Eagle Lake ore lies in a gabbro,

* T. S. Hunt, "Iron and Iron Ores," Geological Survey of Canada, 1866–67, 245. B. J. Harrington, Idem, 1873–74, 195.

but near its contact with the gneisses of the region. Plagioclase, augite and secondary hornblende make it up. In the township of Tudor, in Hastings County, the gabbro near the ore, lacks feldspar and passes into an aggregate of augite and diallage, and the ore itself is largely mixed with pyroxene. The Horton ore lies in typical gabbro, consisting of plagioclase and augite.

	I.	II.	III.	IV.	V.
Fe_2O_3	46.67	39.27	62.39	37.35	29.40
FeO	22.10	21.73	26.93	28.82	29.78
Cr_2O_3	.11	——	——	.12	——
MnO	.23	.37	.45	.31	.22
MO	.31	.27	.22	.26	.43
CoO	.09	.07	.05	.04	.10
Al_2O_3	4.45	4.61	.67	5.01	3.20
SiO_2	7.52	10.77	1.47	10.37	7.82
P_2O_5	.07	.02	.03	.09	.14
S	.82	.11	.06	.04	.06
TiO_2	10.21	13.52	6.41	8 17	17.23
V_2O_5	.35	.52	.23	.29	.63
MgO	3.13	2.34	.33	4.23	5.67
BaO	——	.07	——	——	——
CaO	2.17	4.84	.72	4.40	3.42
Na_2O	.52	.31	——	.57	.61
K_2O	.22	.24	——	.12	.17
CO_2	——	——	——	——	——
Moisture	.37	.44	.31	.47	.38
	99.34	99.50	100.55	100.66	99.26

I. Chaffey Mine, near Newboro, Leeds Co., Ont.

II. Pine Lake ore body, lot 35, concession 4, Glamorgan township, Victoria county, Ontario.

III. Eagle Lake Mine, Bedford township, Frontenac county.

IV. Near Millbridge, Hastings county.

V. In the Township of Horton, Renfrew Co., Range 6.

The deposits of titaniferous iron sands that occur in abundance on the north shores of the St. Lawrence river, near its mouth, have attracted considerable attention and twenty to thirty years ago attempts were made to concentrate them on a large scale and use the product in forges for the manufacture of billets. The sands have been derived from the decomposition of the Norian and other eruptive rocks and together with garnets and other heavy minerals have been concentrated by the currents and waves. The best known are those at Moisie bay near the mouth of the Moisie river, a few miles east of the Bay of Seven Islands, where

as described above there is a large mass of titaniferous ore. Additional sands have been recorded and investigated at other places still further east, such as Mingan, Bersimis, Natasquan, Kagashka and Batiscan.* The layers, rich in iron, are one to several centimeters thick and are in the midst of siliceous sands. They have been dug and have then been concentrated by magnetic machines and by bump tables. Dr. Hunt gives the following determinations and analyses:

	Moisie. A.	Moisie. B.	Moisie. C.	Mingan.	Bersimis.	Natasquan.	Kagashka.	Batiscan.
Sp. gr.	2.82	2.88	2.97	2.84	2.81			
Magnetic part.	46.3	49.3	52.	48.3	34.3	55.7	24.	55.

It is evident from the above that the richness is quite variable, and that with the increase of the specific gravity, as in the three samples from Moisie, the percentage of concentrates also rises.

	Moisie. II.	Moisie. III.	Moisie. I A.	Bersimis. Mag. 34.7 p.c.	Bersimis. Non.-Mag.	Mingan. Mag. 48.3 p.c.	Mingan. Non.-Mag.
FeO	85.79	56.38	71.08	85.56	24.66	80.46	46.31
Fe_2O_3	——	——	——	——	22.44	——	——
TiO_2	4.15	28.95	16.55	3.40	26.95	6.50	31.60
MnO	.40	1.10	——	und.	1.10	.52	1.35
CaO	.90	.95	——	tr.	1.12	.75	1.06
MgO	——	——	——	——	.72	.70	.50
Insoluble	1.95	8.75	5.35	3.85	23.80	4.20	15.50
Total	93.19	96.13	92.98	92.81	100.79	93.13	96.32
Fe	66.73	43.85	52.27	66.56	34.94	65.58	36.

A rich sample of Moisie sand unwashed afforded FeO 70.10, TiO_2 16, Insol. 5.92, Total 92.02, Fe 55.23—49.1% of this was magnetic. The non-magnetic part yielded FeO 58.20, TiO_2 30.72, Insoluble 6.14.

The above analyses are most interesting and significant. Some of the sands are fairly rich iron ores according to the earlier standards, and the concentrates gave excellent values, comparable with the results obtained by artificial crushing. The titanium was lowered by the process but not eliminated as shown by the last four analyses. The washed iron sand at Moisie contained S 0.7, and P 0.007. Titaniferous sands are well known elsewhere in the

*T. S. Hunt has described these sands at length, in the Geological Survey of Canada, 1867–69, 261. See also *Canadian Naturalist*, 1872, VI., 79. In the *Journal of the British Iron and Steel Institute*, 1871, II., 130, there is a description of the efforts which have been made to utilize the sands.

world. They have received some attention at Quogue, Long Island (Fe 40, TiO_2 15, T. S. Hunt), on the shores of Lake Champlain, in New Zealand, and as mineralogical occurrences of no practical importance in many parts of the world. B. J. Harrington* and A. A. Julien† have regarded the iron-sands both, titaniferous and non-titaniferous, as significant in throwing light on the obscure question of the geological history of the magnetite lenses in gneisses. The wide distribution of titaniferous magnetite in basic eruptive rocks of all sorts has made it inevitable that it should be a prominent constituent of the derived sediments.

COLORADO.

The resources of Colorado in iron ore have received more serious attention than those of any state west of the ones that border on the Mississippi river. It was early noted that magnetites were present in the ancient crystallines but in three important cases they have proved to be titaniferous, although observations hitherto made on the exact nature of the wall rock leave much to be desired. The ore that has received most attention and that is best known is the so-called Iron Mountain in Fremont county, about fifty miles nearly due west of Pueblo. Iron Mountain is in the northern portion of the Wet Mountain valley and near the headwaters of Pine creek, a small tributary of Grape Creek. The ore is often described as near Grape Creek. The locality was visited by F. M. Endlich,‡ while in the field for the Hayden Survey in 1873 and he mentions that mining was in operation. Two years later the deposits were examined by M. Chaper,§ a French geologist and several analyses have been recorded of samples taken by him. The most complete description is that of B. T. Putnam,‖ who visited the outcrops for the Tenth Census. It is to Putnam's account that the following notes are chiefly indebted, although as they make slight reference to the wall rock, some additional information has been gained from material in the collections of the Columbia School of Mines. Putnam describes the

* Geological Survey of Canada, 1873-74, 195.

† The Genesis of the Crystalline Iron Ores, Proc. Phila. Acad. Nat. Sciences, 1882, 335.

‡ Hayden's Report for 1873, p. 333.

§ This is quoted by Putnam in the next citation.

‖ B. T. Putnam, Iron Ores in Colorado, Tenth Census, XV., 472–476.

hill as 800 feet long, 500 feet wide and sixty feet high. Seven veins were noted by him and plotted in connection with a magnetic survey of the hill. One or two of them reached fifty feet in cross-section, and several hundred feet of outcrop were noted, not all necessarily of this width. The veins strike N. 10 E. and dip 65° S. E. The only exposure of wall rock is called gray granite, because as the walls have weathered much worse than the ore, the rock seldom shows above the surface. A specimen of gray granitoid rock, which has been for years in the geological collections of Columbia University, is labeled Grape Creek, and is placed with the titaniferous ores, proves to be on microscopic examination a most excellent olivine gabbro.

The following analyses are available and are all taken from Putnam's paper. Tenth Census, Vol. XV., 475–476.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Fe_2O_3	70.50	62.00								
Fe_3O_4			67.76							
TiO_2	14.00	10.00		11.99	12.92	11.61	12.73	13.84	14.86	13.04
SiO_2	8.60	18.60	2.75							
Al_2O_3	4.00	7.00	7.70							
MnO			tr.							
CaO	1.60	1.30	none							
MgO	2.30	1.60	3 20							
P.			tr.	0.025	0.026	0.037	0.011	0.04	0 039	0.026
S.			tr.							
Total	101.00	100.50								
Fe	49.35	43.4		48.89	48.18	46.61	48.35	46.05	47.01	47.42

Nos. I. and II. are from Chaper's report. I. is described as "compact titaniferous magnetite with feldspathic gangue." II. "Oxidized iron sand forming the bed of Iron Creek for several miles above Iron Mountain. III. was made by Charles S. Hinchman, in 1871. All the rest are from Putnam's samples as follows: IV. Outcrop of vein 2. V. Outcrop of vein 3. VI. Outcrop of vein 6. VII. Sample of a pile of ore from vein 3. VIII. Outcrop of vein 4. The special source of IX. and X. is not stated. The numbers of the veins refer to Putnam's map, p. 474.

The high magnesia of I., II. and III. at once strike the reader on looking over the analyses and suggest the basic igneous rocks. In III. the high Al_2O_3 as compared with the low SiO_2 and the abundance of MgO are similar to analyses which have already been commented on and which indicate the presence of spinel. The TiO_2 is not excessive as ores of this type run—and much magnetite is clearly present. The ore is either a titaniferous magnetite or a mixture of magnetite and ilmenite.

A second occurrence of titaniferous ore in Colorado has been met in Boulder County, in the southwestern corner. The locality is known as Caribou Hill and is near the well-known Caribou silver mine and its neighbors, in the Caribou or Grand Island district. Some little prospecting was done for iron years ago, but beyond establishing the character of the ore little has been accomplished. Chauvenet * describes the deposit as a vein of black magnetite, and Putnam states that it is made up of little seams of rich compact magnetite lying in siliceous magnetic rock. The ore is highly magnetic and many boulders cover the hillsides. Unfortunately no determinations of the wall rock have been recorded.

The following analyses have been published:

	I.	II.	III.
Fe	36.93	59.04	35.35
SiO_2	1.16	——	——
TiO_2	36.76	present	present
P	——	0.017	0.022

I. Regis Chauvenet, Biennial Report Colorado State School of Mines, 1886, p. 16. In a paper by the same author on "The Iron Resources of Colorado," Trans. Amer. Inst. Min. Eng., XVIII., 267, 1889, the iron is said to range from 36–38 and the TiO_2 to be 36.

II. and III. are given by Putnam, Tenth Census, XV., 476. No. II. is selected rich ore, No. III. average of a small pile.

The analyses are not sufficiently complete to give an inference as to the wall rock.

A third titaniferous ore body has been identified in the southern part of Gunnison County, in the Cebolla district, which is called Cebolla from the creek of the same name. It is not far from the Lake City branch of the Denver and Rio Grande Railroad. The ore is said by Chauvenet † to constitute an immense ledge and to be traceable over some miles. The ore ranges from 9.38 to 36 % TiO_2, but beyond this general statement no further details are available of ore or wall rock.

MINNESOTA.

The vast area of rocks belonging to the gabbro family, that lies north and west of Lake Superior in Minnesota, has not failed to

* Regis Chauvenet, Notes on Iron Prospects in Northern Colorado; Biennial Report of the Colorado State School of Mines, 1886, p. 16.

† Regis Chauvenet, Iron Resources of Gunnison County, Annual Report State School of Mines, 1887, 18; See also Iron Resources of Colorado, Trans. Amer. Inst. Min. Eng., XVIII., 272. See also A. Lakes, *Colliery Engineer*, XVI., 267, 1896.

yield deposits of titaniferous magnetite of very considerable size. The gabbros themselves have been studied by a number of geologists, but the most complete, connected description has been prepared by W. S. Bayley.* Dr. Bayley refers in his fourth article, as cited below, to the titaniferous magnetites on p. 818. The ores north of Grand Marais and in the region of Iron or Mayhew Lake were recorded in 1879 by N. H. Winchell, and a brief description was published in 1882.† Iron Lake lies near the international boundary and south of Gunflint and Loon lakes. On the south side of the lake beds or masses aggregating 50–75 feet in thickness were found in gabbro and dipping south. Professor Winchell recognized the igneous character of the rock and describes the gradual passage of the ore into wall rock, and the inclusions of various masses of rock in the ore.

Through the courtesy of Dr. U. S. Grant of the Minnesota Geological Survey, the writer has received some specimens of the ore and has made thin sections. Under the microscope they are found to contain much green pyroxene, and a photo-micrograph of the ore is given in the XIX. Ann. Rep. Director U. S. Geological Survey, Part III., Plate LXIII., Fig. B.

The ore forms the "Mayhew Iron Range." An analysis by R. S. Robertson, of Pittsburg, yielded the results under I. No. II. is by C. F. Sidener, and No. III. by J. A. Dodge.‡ No. IV. by Messrs. Dodge and Sidener is an iron sand from Black Beach near Beaver Bay. No. V., by J. A. Dodge, is an iron sand from the south shore of Birch Lake. The Black Beach sand was probably derived, according to W. S. Bayley, from a Keweenawan rock, and therefore a later one than the gabbros cited above. (*Journal of Geology*, I., 819.)

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* The Basic Massive Rocks of the Lake Superior Region, in four parts, viz.: I. Brief History of the Classification of the Gabbros and nearly related Rocks. Journal of Geology, I., 433–456, 1893. II. Sketch of the present state of Knowledge concerning the Basic Massive Rocks of the Lake Superior Region. Idem, I., 587–596. III. The Great Gabbro Mass of Northeastern Minnesota. Idem, I., 688–716. IV. The Peripheral Phases of the Great Gabbro Mass of Northeastern Minnesota. Idem, I., 814–825, III., 1–20.

† See Tenth Annual Report Minn. State Geologist, pp. 80–85, published 1882. Brief reference to these and other similar bodies are made by R. D. Irving, Monograph V., U. S. Geol. Survey, p. 51, 1883, and by M. E. Wadsworth, Bulletin II., Minn. Geol. Survey, pp. 63, 64. All recognize their igneous origin.

‡ II. and III. are taken from Bulletin VI. of Minn. Geol. Survey, p. 141. Robertson's analysis is also given there.

In these analyses where FeO is given in addition to Fe_3O_4 the former has been calculated so as to make FeO TiO_2 with the TiO_2 present. A review of the analyses brings out the interesting fact

	I.	II.	III.	IV.	V.
Fe_3O_4	80.78	53.33	70.29	30.06	——
FeO	——	14.42	2.01	2.23	——
TiO_2	12.09	16.03	2.23	2.48	36.77
SiO_2	2.02	11.37	20.90	65.17	5.19
Al_2O_3	2.58	1.32	1.75	tr.	2.95
Cr_2O_3	2.40	——	——	——	——
CaO	tr.	.10	tr.	tr.	tr.
MgO	——	2.73	2.63	tr.	0.35
P_2O_5	0.03	.01	none	——	none
S	——	tr.	——	——	——
Total	99.90	99.31	99.81	99.94	——
Fe	58.48	49.41	52.46	23.50	41.12

of the presence of chromic oxide in considerable amounts in I. It doubtless would have been found in the others had it been looked for. Some magnesia was also probably present, although not determined. The relatively high percentage of Al_2O_3 as compared with the SiO_2 leads one to infer that the ore contains an iron spinel, as it is otherwise, in the absence of magnesia, difficult to account for the various oxides. In II. and III. much of the iron must be combined with the silica, unless quartz is present, an unlikely assumption. E. Le M. Hoare states that several analyses led him to conclude that the total iron and titanium were fairly constant, but that the TiO_2 varied from 6–13%, the iron varying inversely. The foregoing analyses do not fully corroborate this conclusion as the $Fe_3O_4 + TiO_2$ are respectively, 92.87, 83.78, 74.53.

The ore is said to be abundant in many places west, southwest and southeast of Mayhew lake.* The same region affords magnetites devoid of titanium. Bayley also mentions titaniferous varieties from the shores of Little Sassanaga lake. (*Jour. Geol.*, I., 818.) Masses of titaniferous ore are known within the city limits of Duluth, where they are an enrichment of the gabbro with titaniferous magnetite or ilmenite.* The association of these ores with the gabbros is so characteristic and wide-spread that they have been collectively described by N. H. & H. V. Winchell as the "Gabbro Titanic-iron Group."† W. S. Bayley records in the ores

* Bulletin VI., Minn. Geol. Survey, 136.

† Bulletin, VI., p. 123.

studied by him tiny yellowish green grains of olivine, but the quantity is so small that they do not seriously affect the appearance of the rock.

In August, 1895, at the Springfield meeting of the Geological Society of America C. R. Van Hise stated, in discussing a paper by J. F. Kemp on the Adirondack titaniferous ores, that the ores on Lake Superior resembled the former in their geological relations, but that there had been some infiltration of iron since their formation. *

New Jersey.

For thirty years or more the iron-masters of New Jersey have known that the state contained, in addition to the usual non-titaniferous magnetites, another series, more or less richly provided with this element. Careful analysis has shown the very general presence of titanium in amounts from a trace to one per cent. in almost all the magnetites, but in addition to these, there are others which range up to nine or ten. The greater number of the mines of this character are found in the southwestern portion of the Musconetcong belt, from Schooley's Mountain to and across the Pennsylvania line, but scattered occurrences are met in other belts and further to the northeast than Schooley's Mountain.† The wall rocks of the titaniferous mines have seldom if ever been described as other than gneisses of various kinds, and this general determination does not furnish the necessary clue to their original character sufficiently well to warrant the drawing of inferences. In only two instances have they been microscopically determined and interpreted, one at the Hibernia mine by J. E. Wolff,‡ and the other on Jenny Jump Mountain by L. G. Westgate.§ Dr. Wolff favors

* Bulletin Geol. Soc. of America, VII., 488, 1895.

† In explanation it may be stated that the New Jersey magnetites were grouped in four belts as far back as 1873 and the belts were named in that year from southeast to northwest the Ramapo, the Passaic, the Musconetcong and the Pequest. The fullest account of the belts will, however, be found in the Report for 1879, pp. 38 and ff. The belts correspond to the linear outcrops of Archean gneisses, which cross the state from southwest to northeast and which are in some degree separated by infolded strata of Paleozoic age. The Report for 1879 records the mines of each belt.

‡ J. E. Wolff—Geological Structure in the Vicinity of Hibernia, N. J., and its relation to the Ore Deposits. Annual Report of the State Geologist of New Jersey, for 1893, p. 359.

§ The Geology of the Northern Part of Jenny Jump Mountain, Warren County. Annual Report of the State Geologist of New Jersey, for 1895, p. 21.

an origin for the gneisses at Hibernia by the metamorphism of a regularly stratified series of sediments. Mr. Westgate is in doubt about the light-colored feldspathic gneisses, but favors an eruptive origin for the dark hornblendic varieties. Neither of these localities, so far as known to the writer, contains the richly titaniferous ores, and the citations are only of importance in this connection in so far as Mr. Westgate found reason to believe that squeezed eruptives were present. The question as to whether the titaniferous ores are or are not associated with intrusions of gabbros is an interesting one and the presumption is that such will prove to be the case, although, of course, the intrusions are now sheared and metamorphosed to hornblendic or pyroxenic gneisses and amphibolites.

The following analyses indicate the character of the ore. They are arranged along the belts from southwest to northeast.

MUSCONETCONG BELT.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Fe_2O_3 FeO			} 69.40	69.34				} 89.39	82.78
TiO_2	1.40	4.7	10.52	1·.60	8.97	1.05	2.45	7.50	6.40
SiO_2			7.92	5.40					
Al_2O_3			4.36	9.29					
MnO	none		0.19			none	none		
CaO			0.46	0.39					2.70
MgO			2.52	3.35					0.91
Insol.		49.7						2.20	2.40
P_2O_5			0.02	tr.				0.16	2.56
P	0.029	tr.				.367	0.167		
S	7.59	tr.	1.46	1.21		0.088	0.055	0.27	0.041
Total			96.85	100.58				99.52	97.79
Fe	56.13	37.5	50.60	50.21		56.97	57.62	64.77	59.32

	X.	XI.	XII.	XIII.
Fe_2O_3 FeO				
TiO_2	9.80	4.20	4.20	5.90
SiO_2				
Al_2O_3				
MnO	tr.	tr.		
CaO				
MgO				
Insol.				
P_2O_5				26.6
P	0.14	0.39	0.33	tr.
S	none	——	0.05	——
Total				
Fe	62.23	40.25	58.55	49.5

	Pequest Belt.		Ramapo Belt.
	XIV.	XV.	XX.
Fe_3O_4	85.56	70.26	
TiO_2	1.45	5 00	
S	none	tr.	
P_2O_5	tr.	0.19	
MnO	none	0.45	
Insol.	9		
Fe	61.96	50.88	
Fe			54.46
TiO_2			7.70
S			0.31
P			0.04
Mn			0.00
Insol.			22.50

Passaic Belt.

	XVI.	XVII.	XVIII.	XIX.
Fe_3O_4	89.33	90.47	95.98	78.30
TiO_2	1.50	2.72	1.95	1.44
Al_2O_3		1.91	0.66	1.17
MnO	none	——	——	0.25
CaO		none		4.03
MgO		0.72	0.43	tr.
Insol.	8.10	5.80	4.10	12.60
S	none	none	——	0.01
P_2O_5	tr.	tr.	0.06	3.39
		101.62	103.18	101.19
Fe	64.69			

Musconetcong Belt.

I. Hager Mine, Hunterdon Co., Holland township, *N. J. Geol. Rep.*, 1879, 62.

II. Bloom or Little York Mine, Hunterdon Co., Holland township, *Idem*, 1875, 35.

III. Church or Van Syckle Mine, Hunterdon Co., Bethlehem township, J. B. Brit. ton, cited by R. W. Raymond, *Trans. Amer. Hist. Min. Eng.*, XXI., 275, 1892. Also H_2O, 0.40. Organic matter, 2.69 (?) Another analysis not given in full gave TiO_2 15.05, and others by Isidor Walz, TiO_2, 15.05; 13.30 (with Fe 54.04) 12.36; 14.45 (with Fe, 55.02); 9.83; 12.19; 10.37; 9.82; 12.02. One determination gave P. 0.007. Three determinations gave V_2O_5, 0.38; 0.31; 0.13.

IV. Same Mine, *N. J. Geol. Survey*, 1873, 55.

V. Johnson Mine, near Glen Gardner, Lebanon township, Hunterdon Co., B. F. Fackenthal. *Trans. Amer. Hist. Min. Eng.*, XXI., 279, 1892.

VI. Hann Farm, Washington township, Morris Co., *N. J. Geol. Rept.*, 1879, 67.

VII. Marsh Mine, Washington township, Morris Co., *Idem*, p. 69.

VIII. and IX. Naughtright Mine, Washington township, Morris Co., *Idem*, 1878, 100.

X. and XI. Cramer Mine, Mt. Olive township, Morris Co., *Idem*, 1877, 49.

XII. Haggerty Mine, Allamuchy township, Morris Co., *Idem*, 1879, 76.

XIII. Pequest Mining Co., Allamuchy township, Morris Co., *Idem*, 1875, 35.

Pequest Belt.

XIV. Baker or Bulgin Mine, Independence township, Warren Co., *N. J. Geol. Rept.*, 1880, 125.

XV. Day Mine, Independence township, Warren Co., *Idem*, 1880, 126.

PASSAIC BELT.

XVI. Stony Brock Mine, Pequannock township, Morris Co., *Idem*, 1876, 54.

XVII., XVIII., XIX. All from Ringwood Mines, Pompton township, Passaic Co. XVII. is Cannon No. 4; XVIII., Old Blue; XIX., Keeler; *Idem*, 1873, 53.

RAMAPO BELT.

XX. Beers Mine, Hanover township, Morris Co., *Idem*, 1878, 99.

A critical survey of these analyses brings out the fact that, as compared with other titaniferous districts, the ores are not rich in titanium, although those from the Church mine (III. and IV and footnote), exceed ten per cent. A number of others approximate this value, and another group has values not far from five per cent. Among the analyses Nos. III. and IV. of the Church are alone sufficiently complete to justify interpretations on the standard of rock analyses. The peculiarly high Al_2O as compared with SiO_2, and, at the same time, the excess of MgO over CaO are both features that are exceptional among iron ores and rather characteristic of the titaniferous variety. As remarked several times in previous pages, they indicate strongly the presence of spinel. The relations also suggest the genetic connection of the ore with some rock of the gabbro group, on the analogy with much experience elsewhere gained.

The analyses in some instances conform to the general rule that high TiO_2 implies low phosphorus, but not always, No. IX., for example, is very rich in the latter (2.56 P_2O_5), and has a respectable percentage of the former (6.40 TiO_2). Nos. X., XI. and XII., with considerable percentages of TiO_2 (9.80, 4.20, 4.20) are by no means low in phosphorus (0.14, 0.39 and 0.33 respectively). The sulphur varies in much the same way. The presence of vanadic acid in the Church ore is interesting (see footnote to analysis III.).

NEW YORK.

The titaniferous ores of New York are found in Essex County in the eastern Adirondacks and on the east bank of the Hudson, south of Peekskill. In the latter district they are comparatively low in titanium but are extremely high in alumina, but in the former they present the usual ranges in composition of ores of this type, and the associated rocks are various members of the gabbro group in both instances. In the Adirondacks the ores are con-

tained either in basic gabbros or in anorthosites as the rocks which are nearly pure labradorite are now generally called. The former are especially developed in the townships of Westport and Elizabethtown not far from Lake Champlain, while the latter are most extensively met in the heart of the mountains fifty miles from the Champlain Valley and near Lake Sandford. The basic gabbros are also met in the latter locality and one great belt of ore appears to be an enriched gabbro dike.

In Westport the Split Rock mine is situated on a steep, rocky mountain side just above the lake and is based on an ore body that is ten feet or more thick and that runs into the ledge, with a dip of about 50 degrees to the south. The ore is rather lean and has considerable amounts of bisilicates in it. Its composition and that of the wall-rock are shown by the analyses given below. There are a few other small prospects in Westport. In Elizabethtown, which is the next township to the west, there are larger ore bodies on Tunnel Mountain, and near Little Pond, and smaller ones at several additional points. Their composition is also shown below. All are rather lean. Around Lake Sanford the ore occurs in very large masses that are comparable with those in Canada. In the anorthosite it forms coarsely crystalline masses, often with large, green, included labradorites, and on analysis it runs quite rich in iron. There is in addition what appears to be a huge dike of finely crystalline, black ore, that shows phases much like the basic gabbros further east. The mineralogy and geology of these localities have been fully discussed by the writer and it is unnecessary to again go into them in detail.* A compilation of the analyses that have thus far been made will, however, prove of interest as a matter of comparison and of reference.

* E. Emmons, Report on the Second District N. Y. Natural History Survey, 1842.

J. F. Kemp, Fifteenth Ann. Rept. N. Y. State Geologist, 608, 1898; Nineteenth Ann. Rep. Dir. U. S. Geol. Survey, Part III., 377, 1899. The latter is the most complete paper.

G. W. Maynard, Journal British Iron and Steel Institute, 1874, No. I.

A. J. Rossi, Trans. Amer. Inst. Min. Eng., XXI., 832, 1893; The Iron Age, Feb. 6 and 20, 1896.

Ores in Gabbro.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Sp. gr.	3.090	4 138				3.199		3.090	4.138		4.41	3 833
SiO_2	47.88	17.90	16.46	21.64	10.26		13.35	44.77	11.73	21.42		
TiO_2	1.20	15.66	14.70	13.15	16.37	10.55	16.45	5.26	12.31	5 21	18.82	13.07
Cr_2O_3	tr ?	.51				0.25	0.55			none.	0.75	0.37
Al_2O_3	18.90	10 23	0.34	11.86	9.35		8.75	12.46	6 46	7 03		
Fe_2O_3	1.39	15.85	38 43	23.77	30.36	11.52	20 35	4.63	30.68	30 34	26.30	11.16
FeO	10.45	27.94	23.40	21.24	25.46	21.34	28.82	12.99	27 92	22 81	29 78	28 35
NiOCoO	.02	not det.						tr.	——			
MnO	.16	little	.23	0.87	0.47			0.17		tr.		
CaO	8.36	2.86	3.54	3.54	7.75		2 15	10.20	3.95	3.59		
SrO	tr.	undet.										
BaO	tr.	undet.						tr.				
MgO	7.10	6.04	2.13		0.13	——	6.63	5.34	3.35	6.92		
K_2O	.81	undet.						0.95	0.26	0.41		
Na_2O	2.75	undet.						2.47	.50	0 53		
Li_2O	fl. tr.											
$H_2O - 110°$	.18	1.33					1.68	0.12	0.64	0 95		
$H_2O + 110$	.43							0.48				
P_2O_5	.20	.04				0.46	0.02	0.28	1.82	0.14	tr.	0.32
V_2O_5	tr.	.55				0.34	0.61	——	0 04		0.62	0.50
CO_2	.12	.10					0.17	0.37	0.32			
S	.07	.14				0.10	0 09	0.26	0.04	0 c4	0.06	0.10
Total,	100.02	99.15				44.56	99 65	100.75	99.02	99 39	76.33	53.87
Fe		32.82	44.77	32.59	40.42	24.65	35 99		44.19	38 978	41.57	29.868

I. Gabbro, Wall-rock, Split Rock Mine, Anals. by W. F. Hillebrand, XIX. Ann. Dir. U. S. Geol. Surv. Part III., p. 402. 1899.

II. Ore, Split Rock Mine, by W. F. Hillebrand, *Idem.*

III. Ore, Split Rock Mine, by G. W. Maynard, Jour. British Iron and Steel Inst., 1874.

IV. Ore, Kingdom Works, Mine uncertain, *Idem.*

V. Ore, Iron Mtn., Elizabethtown, Mine uncertain, *Idem.*

VI. Ore, Tunnel Hill, foot, Analyst, W. F. Hillebrand, same as I., p. 404.

VII. Ore, Tunnel Hill, summit, Analyst, W. F. Hillebrand, *Idem*, p. 405.

VIII., IX. Wall-rock-Gabbro and ore, respectively, Lincoln Pond, Elizabethtown. Former by Geo. Steiger, latter by W. F. Hillebrand, *Idem*, p. 407.

X. Ore, Oak Hill, Elizabethtown, by W. F. Hillebrand, *Idem*, p. 408.

XI., XII. Ore, from two pits near Little Pond, Elizabethtown. W. F. Hillebrand *Idem*, p. 406.

ORES NEAR LAKE SANFORD—CHIEFLY IN ANORTHOSITE.

			MILLPOND PIT.			CHENEY.	
	1.	2.	3.	4.	5.	6.	7.
SiO_2	1.09	3.67	1.53	——	0.91	——	9.79
TiO_2	10.73	13.38	19.74	20.24	20.49	8.25	15.77
Al_2O_3	0.44	1.50	3.50	——	——	——	7.12
CaO	tr.	little	little	——	——	——	8.89
MgO	tr.	0.50	1.60	——	——	——	3.00
Mn_3O_4	0.13	——	——	——	——	——	——
Fe_3O_4	87.20	82.37	73.62	——	——	86.53	55.64
P	none	0.017	0.037	——	——	0.39	——
S	none	0.068	0.08	——	——	0.74	1.00
Fe	63.45	59 56	53.62	55.62	54.80	62.15	40.33

				SANFORD ORE.			
	8.	9.	10.	11.	12.	13.	14.
SiO_2	0.87	2.46	1.39	1.34	1.39		
TiO_2	10.91	20.03	19.52	18.70	14.52	4.0	47.50
Al_2O_3	0.53	3.50	4.00	——	5.81		
CaO	——	——	——	——			
MgO	——	——	——	——			
Mn_3O_4	——	——	——	——			
Fe_3O_4	87.60	70.73	70.80	71.03			
P	——	——	0.022	——			
S	——	——	0.028	——			
Fe	62.65	51.21	51.30	51.44	56.60	62.66	56.86

The analyses were made by the following chemists: Nos. 1, 8, Habershaw; Nos. 2, 3, 4, 7, 11, Rossi; Nos. 5, 10, Ledoux; No. 6, Wilbur; No. 9, Ricketts and Banks; No. 12, Miss White; No. 13, 14, C. F. Chandler. No. 13 is of magnetic concentrates, No. 14 of tailings. In this case it would appear that magnetic concentration had effected a partial elimination of the titanium.

As all geologists familiar with the special study of rocks know, there is an area of about 25 square miles just south of Peekskill,

on the Hudson, that consists of rocks of the gabbro family, and that was named by Professor J. D. Dana, the Cortlandt series. In connection with these intrusives, but in relations that deserve further study, deposits of a very aluminous iron ore have long been known to exist and have received some attention as a source of iron, and still more as a source of emery. They are not rich in titanic oxide, ranging from 0.15 to 4.15 but they are very high in alumina, for which reason J. P. Kimball urged their employment as far back as 1874, as a lining for puddling furnaces and as a source of multi-basic slags. Under the microscope, they exhibit green spinel (hercynite), magnetite, and pale-blue corundum. These mineralogical characters were first recognized by G. H. Williams. They are a most striking parallel with the ores at Routivara, Sweden, which will be subsequently described, and with two cases in North Carolina, which are not, however, titaniferous to any marked degree.

	I.	II.	III.	IV.	V.	VI.	VII.
TiO_2	3.83	3.52	4.41	2.41	3.90	1.90	4.15
FeO	21.14	18.49	17.92	45.86			
Fe_2O_3	25.86	28.21	28.70				
SiO_2	1.13	1.04	2.88	0.51	0.32	6.82	13.97
Al_2O_3	45.58	36.46	34.47	39.36	41.28	45.29	20.95
Cr_2O_3	——	——					
MnO	——	——		0.55			
CaO				0.47			
MgO				7.18			
P_2O_5	0.16	0.09	0.16	0.22			
H_2O				1.18			
Fe	34.54	34.13	34.03	34.44	35.82	29.16	40.32

	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.
Al_2O_3	31.93	40.77	37.78	37.43	36.49	41.66	46.53
Fe_2O_3	18.19	18.37	24.35	21.17	21.36	23.71	32.31
MgO	7.41	6.73	7.92	7.20	8.39	7.91	9.43
Magnetic Iron	34.20	32.01	17.37	19.81	22.77	14.76	8.98
Silicious Residue	6.42	1.04	11.19	13.14	10.08	11.48	2.42
TiO_2	1.12	1.08	0.62	0.65	0.67	0.54	0.51
Sulphur	0.04	0.04	0.02	0.02	0.02	0.01	0.01
Phosphorus	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Total	99.31	100.04	99.25	99.42	99.78	100.07	100.19

I.–III. inclusive from paper by J. P. Kimball. *Trans. Amer. Inst. Min. Eng.*, IX., 19, 1881. IV. to VII. inclusive, *Amer. Chemist*, IV., 1874, 321. I., II. and III. by T. M. Drown, IV. through VII. by C. F. Chandler and F. A. Cairns. No. IV. had also FeS_2, 2.63.

VI.–XII. were made by Professor Thomas Egleston, for the New York Emery Co., and are copied from the paper by G. H. Williams on the "Norites of the Cortland series," *Amer. Jour. Sci*, March, 1887, p. 197. Dr. Williams mentions many localities for the ores and gives extended data regarding their mineralogy. Although Dr. Williams was more intent on the mineralogical composition of the ores than on their geological relations, he mentions that they "appear to be segregations in the norite" (p. 194), and that pyroxenites favor the vicinity of the mines. Professor J. D. Dana has also given some details regarding them in the *American Journal of Science*, September, 1880, pp. 199, 200; and of interest in connection with views of their igneous origin is the paper by Josef Morozewicz,* in which he describes the artificial production of spinels and corundum.

North Carolina.

Titaniferous ores are quite widely distributed in North Carolina and form a considerable proportion of the magnetites of the state. Along the western border they are present in the northwestern county, Ashe, and appear again in Mitchell, Yancey, Madison and Macon, along the western border of the state. Further east they have been recognized in Caldwell Co., as a somewhat isolated occurrence. Still further in the same direction a northeast and southwest belt begins in Rockingham and Guilford counties on the north and, with several breaks, appears again in Davie, Davidson, Catawba and Lincoln counties to the south. The trend of these ores in longitudinal alignment has been long recognized by the North Carolina geologists and the "titaniferous belts" is a frequent phrase in the reports. Not only in the large way, but also in the relationships of smaller groups, the same lineal arrangement manifests itself.

The ore bodies do not reach the vast dimensions of those cited from the Adirondacks or the western states or Canada, but usually display from 5 to 15 feet of cross section and a marked lenticular shape from the widely prevalent dynamic metamorphism. The character of the wall rock has seldom been determined with such accuracy as to give ground for inferences as to its certain, original character, but hornblendic gneiss or schist is the commonest one mentioned in the North Carolina reports,† and one cannot but suspect that original gabbros, or their relatives, are present. Some selected analyses by belts will give an idea of the range of the

* Experimentelle Untersuchungen über die Bildung der Minerale in Magma, *Tschermaks Min. und Petrog. Mittheil.*, XVIII., 1, especially pp. 25–68.

† Bulletin I. of the N. C. Geological Survey, on the Iron Ores of the State, by H. B. C. Nitze is especially valuable.

ores—but a very considerable number in addition will be found in Bulletin I., just referred to. The ores have been utilized both in the forges and to some extent in the blast furnaces of the several belts, but particularly in Rockingham and Guilford counties.

COUNTIES.	ASHE.			ALLEGHANY, MITCHELL, MADISON, CALDWELL.				
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	6.35	9.90	4.75	6.20	1.46	0.83	6.63	7.75
TiO_2	4.69	6.03	8.91	4.86	4.80	37.88	15.00	41.22
Fe_2O_3	——	——	——	——	——	——	——	——
FeO	——	——	——	——	——	——	——	——
MnO	——	——	——	——	——	0.81	——	1.40
Al_2O_3	——	——	——	——	——	9.51	——	——
Cr_2O_3	0.505	0.630	1.19	——	——	——	——	——
CaO	——	——	——	——	——	2.57	——	4.14
MgO	——	——	——	——	——	0.93	——	7.65
P	0.008	0 025	0.021	0.047	0.009	tr.	0.06	0.140
S	0.061	0.137	0.112	0.038	0.025	0.09	0.021	0.013
V_2O_5								
H_2O								
Fe	57.66	46.81	52.23	54.72	65.32	36.26	36.00	28.24

COUNTIES.	GUILFORD, ROCKINGHAM, DAVIDSON.		GUILFORD.						
	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
SiO_2	1.31	4.71	0.76	5.68	0.40	1.84	1.30	12.75	26.80	0.50
TiO_2	13.60	13.74	13.52	11.67	11.95	13.27	12.35	15.35	16.20	12.27
Fe_2O_3										
FeO										
MnO		0.14								
Al_2O_3	4.26	8.68	1.68	5.08	1.06	2.30	2.54	5.17	8.87	3.62
Cr_2O_3	0.72	0.34	0.46	0.48	1.07	0.65	1.10	1.25	0.43	0.57
CaO			0.45	0.76	0.24	0.58	0.51	0.90	0.40	0.63
MgO			2.79	2.61	1.99	2.01	2.41	4.14	10.30	2.04
P	tr.	0.023								
S	tr.	0.089								
V_2O_5										
H_2O										
Fe	55.06	48.41	57.68	52.68	59.03	56.21	56.41	41.95	21.63	57.32

Counties.	Rockingham.		Rockingham and Guilford.					Rockingham—Dannemora Mine.		
	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVI. con.	
SiO_2	1.80	0.74	0.75	1.89	1.04	1.50	0.52	4.70	FeS_2	0.133
TiO_2	14.36	13.92	12.08	8.72	12.32	8.65	13.74	13.71	NiS	0.01
Fe_2O_3			79.78	82.68	81.30	——	——	43.05	CoS	0.03
FeO						——	——	23.51	CuS	0.01
MnO	1.23	1.06	0.126	0.189	tr.	0.054	.315	0 15	K_2O	0.03
Al_2O_3	2.66	3.82	4.62	3.93	3.87	2.90	4.50	8.66	Na_2O	0.05
Cr_2O_3	0.97	1.07	0.32	0.40	tr.	0.83	tr.	0.34	CO_2	0.07
CaO	0.69	0 55	0.13	0.17	0.64	0.75	0.72	1.42	C	0.06
MgO	3.09	1.80	2.04	1.36	0.49	2.02	0.54	2.96		
P	——	——	——	——	none	tr.	none	0.022		
S	——	——	——	——	tr.	none	none			
V_2O_5			tr.							
H_2O					0.34			1.17		
Fe	54.17	56.61	57.77	59.95	58.52	60.41	57.30	48.41		

Nos I., II. and III. are taken from Bulletin I., N. C. Geol. Survey, pp. 159, 160.
No. IV., Idem, p. 125.
No. V., Idem, p. 182.
No. VI., North Carolina Geol. Surv., II., 181, 1893.
Nos. VII. and VIII., Bulletin I., N. C. Geol. Surv., 120.
Nos. IX. through XX., *Idem*, 63–67.
Nos. XXI. through XXV., J. P. Lesley, Notes on the Titaniferous Iron Ore Belt near Greensboro, N. C., Amer. Phil. Soc., XII., 154–156.
No. XXVI., Bailey Willis, Tenth Census, XV., 310.

These analyses are given with the above completeness because they serve to bring out so perfectly the characters of this group of ores. While the TiO_2 is usually between 10 and 15 per cent., it falls to 4.69 in I., and rises to 37.88 in VI. Chromium is almost always present and it is fortunate that it has been determined in so extended a series. The alumina far exceeds the silica in almost all cases, and with it the magnesia shows sympathetic variation. The latter exceeds the lime; vanadic acid was found in the one case where it was tested for; phosphorus and sulphur are low so far as determined.

Dr. F. A. Genth analyzed some years ago, two samples of what he called emery ore, from a locality in Rockingham or Guilford counties, but which is not exactly stated. The analyses are of extreme interest when taken in connection with the peculiar ores of Routivare, Sweden, and of Westchester County, New York.

	I.	II.
SiO_2	1.39	0.98
TiO_2	0.78	2.42
Al_2O_3	52.24	44.86
Cr_2O_3	0.30	tr.
CaO	0.84	0.91
MgO	0.68	3.27
Fe	30.97	33.52

The analyses are taken from Bulletin I., N. C. Geol. Surv., p. 66.

The analyses lead one to infer the presence of spinel in some form, and in it the iron oxide is no doubt chiefly present; some corundum is also probable.

The magnesia is so low that much pleonaste is impossible. The probabilities favor hercynite, the iron spinel, and a comparison of thin sections with others of the Westchester variety would be of extreme interest. The titanium in the North Carolina ores is low.

Rhode Island.

As Rhode Island was among the first of the states to be settled, it is not surprising that the large mass of iron ore forming Cumberland Hill, a few miles north of Providence was early discovered and utilized. Mixed with the Cranston limonites the ore was smelted for iron, with which to make cannon, as early as 1703, and the same employment continued through the last century and especially during the Revolution.* The ore forms a low hill that rises above meadows on either side. It was measured by C. T. Jackson in 1840 and found to be 462 feet long, 132 feet broad and 104 feet high, dimensions that imply an enormous body of ore. The mass has been most carefully studied petrographically by M. E. Wadsworth, who recognized it in 1881 to be a peridotite exceptionally rich in titaniferous magnetite. The thin sections chiefly exhibit magnetite and serpentinized olivine but on one side of the hill Dr. Wadsworth found a variety with considerable plagioclase in which flakes of biotite also occur.

* M. E. Wadsworth, A Microscopical Study of the Iron Ore, or Peridotite, of Iron Mine Hill, Cumberland, Rhode Island, Bull. Mus. Comp. Zool. VII., 183, 1881. Dr. Wadsworth quotes a report of the Rhode Island Society for the Encouragement of Domestic Industry made in 1869. Other notes by him will be found in his Lithological Studies and in Bulletin of the American Iron and Steel Association, Nov. 20, 1889, p. 314.

Thin sections from specimens collected by the writer at the north end of the hill consist of serpentine, presumably from olivine, and of magnetite.

Dr. Wadsworth recognized the close resemblance of the ore or rock to that of the famous iron mine at Taberg, Sweden, which had been studied about five years earlier by Sjögren as will be elsewhere described in this paper.

The Taberg ore consists of titaniferous magnetite and olivine, the "magnetite-olivinite" of Sjögren, Törnebohn has shown that the richer ore to which the name magnetite-olivinite applies, is associated with leaner portions that have much basic plagioclase and occasional biotite, and that it passes by gradual transitions into a rock called olivine-hyperite, meaning one intermediate between olivine-diabase and olivine-gabbro. The close parallelism between Cumberland Hill and Taberg is remarkable. Dr. Wadsworth recognized that an eruptive origin would alone reasonably account for the Rhode Island occurrence and rightly interpreting it as an ultrabasic peridotite, he named it Cumberlandite. The nearest country rock lies at a distance of a hundred feet, and is mica schist. An intervening meadow masks the contacts.

Much interest has been attracted from time to time to this hill as a source of ore, especially for steel, but the low percentage of iron, combined with the disadvantages of titanium have prevented serious development.* It has lately received high commendation as a supply of macadamizing material† and as a source of boulders of a peculiar and easily recognized kind it has thrown much light on the phenomena and direction of movement of the great ice sheet.‡

The following analyses have been made available:

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* A. L. Holley, Notes on Iron Ore and Anthracite Coal of Rhode Island and Massachusetts, Trans. Amer. Inst. Min. Eng., VI., 224, 1877.

† N. S. Shaler, The Geology of the Road-building Stones of Massachusetts, with some consideration of similar materials from other parts of the United States. Sixteenth Ann. Rep. U. S. Geol. Surv., Part II., 321.

‡ N. S. Shaler, Conditions of erosion beneath deep glaciers, based upon a study of the boulder train from Iron Hill, Cumberland, R. I. Bull. Mus. Comp. Zool, XVI., 185.

	I.	II.	III.	IV.	V.	VI.
Fe_2O_3	27.60	44.88	45.62	58.50		
FeO	12.40					
TiO_2	15.30	9.99	9.93	3.66	9.35	9.86
SiO_2	23.00	22.87	20.85	26.33		
Al_2O_3	13.10	10.64	5.55			
MnO	2.00	2.05				
CaO		0.65	.73	.65		
MgO	4.00	5.67	16.45	6.80		
Zn		0.20				
H_2O	2.60	3.05	——	4.06		
P_2O_5	——	——	tr.		P. 0.026	0.020
S	——	——	tr.	——	0.057	0.057
Total	100.	100.	99.13	100.		
Fe	28.96	32.49	33 03	42.35	32.80	32.84

I. C. T. Jackson, Geol. Survey of Rhode Island, 53, 1840.

II. R. H. Thurston, quoted by M. E. Wadsworth, *Bull. Mus. Comp. Zool*, VII. 185, 1881.

III. T. M. Drown, quoted by M E Wadsworth, *Memoirs Mus. Comp. Zool.*, Vol. XI., Table III, p. xvi, 1884.

IV. Chilton for A. L Holley, *Trans. Amer. Inst. Min. Eng.*, V'., 226, 1878.

V. Capt John Pitman for Tenth Census, Vol. XV., p. 567. Sample by Bailey Willis, natural ore.

VI. Same as last but dried.

The analyses indicate that the ore is moderately rich in TiO_2 as these ores run, but that it is hopelessly low in iron for use raw, under modern conditions. Concentration is the possible outlook, but for many years, unless the ore should furnish some peculiar brand of iron, even this is improbable. As revealed by the thin sections, concentration would merely remove the titaniferous mineral from the serpentine or olivine, and would increase the titanium while increasing the iron. Indeed, samples taken systematically some years ago by W. B. Kunhardt from the entire hill, were concentrated by a Ball and Norton machine. The concentrates gave on analysis, TiO_2 21.65, phosphorus 0.0214 per cent. As compared with the general average of about 10 per cent. TiO_2 in the analyses just quoted, this shows a doubling of the TiO_2 and more.

In Nos. II., III. and IV. the metallic iron is reckoned on the assumption that the Fe_2O_3 and FeO form Fe_3O_4, which is, of course, unjustified, but the margin of error is very small.

VIRGINIA.

The writer is informed by his friend, Professor H. D. Campbell, of Lexington, Va., that a large body of titaniferous ore exists in

the Blue Ridge, east of Lexington. Analyses are not, however, available, nor have geological descriptions been prepared.

WYOMING.

The existence of great deposits of magnetic iron ore in the mountains north of the present site of Laramie, Wyo., was noted as early as 1849–50 by Lt. Howard Stansbury, U. S. A. Lt. Stansbury was commissioned by Col. Abert, of the Topographical Engineers, to execute a survey of the Great Salt Lake Basin and surrounding country, and the report also contains notes on the portions of Kansas and Wyoming traversed by him.* Stansbury noted in the valley of Chugwater Creek and on the neighboring hills nodules of iron ore which impressed him as very rich. Dr. F. V. Hayden visited Chugwater Creek in 1859 while attached to an expedition under Captain, afterwards Gen., W. F. Raynolds, to the headwaters of the Yellowstone and Missouri rivers. Dr. Hayden noted the boulders of ore but not until 1868 did he trace them to their source and discover the great size of the masses.† The ore is described as interstratified among the red feldspathic granites which compose the nucleus of the range. "The ore beds incline in the same direction with the granites, and have the same joints and cleavage, and the examples of slickensides are numerous. They are not continuous and are confined to a restricted area, yet Mr. Whitehead traced one of the beds a distance of over one and a-half miles. The ore is located much like that in the Lake Superior region, and is probably of the age of the Laurentian rocks of Canada." From the ore in place, thousands of tons of boulders are distributed down the valley of the "Chug." An analysis made at the School of Mines of Columbia College, by J. P. Carson is given under I. below and is taken from Hayden's Report.

The ores were also visited by the geologists of the Survey of the Fortieth Parallel and a careful and valuable description of the geological relations has been written by Arnold Hague.‡ Mr. Hague describes the ore as forming Iron Mountain, "a mass of titaniferous iron or ilmenite," that "rises about 600 feet above the stream bed, is irregular in form but has a somewhat oval-shaped

* Exploration and Survey of the Valley of the Great Salt Lake—Howard Stansbury, Capt. Top. Eng., Philadelphia, 1852.

† See F. V. Hayden, U. S. Geological Survey of the Territories, 1870, p. 14.

‡ Reports of the Survey of the Fortieth Parallel, Vol. II., pp. 12–16, 1877.

outline. It occurs intercalated in the granite, standing nearly vertical, with the walls in places sharply defined; this is the case in the cañon where the dark iron body resembles a broad dike, which rises to the top of the cañon-wall. Frequently huge masses of granite are enclosed in the iron and again the iron body puts out into the surrounding granite. The main deposit is nearly a quarter of a mile in length, with a strike a little to the west of north. * * * To the north the main deposit terminates somewhat abruptly; but southward it crosses the cañon, and may be traced cropping out through the granitoid rocks, with the same general strike for nearly two miles, in the direction of Pebble Creek. These outcrops vary much in size, mostly mere seams and small irregular patches of iron, which disappear in the surrounding granite." * * * The ilmenite occurs chiefly as a compact massive deposit, iron black in color, with a submetallic lustre." The above relations strongly suggest an intruded origin, although this phase of the subject is not touched on by Mr. Hague. The granite is an orthoclase granite, with few plagioclases and an analysis by R. W. Woodward is given under IV. below. Granite is an unusual wall rock for titaniferous magnetites, but gabbro, it is interesting to note, occurs in the immediate vicinity. Mr. Hague gathered it in the region east of Iron Mountain and of Chugwater and Horse Creeks, where it forms low, irregular-shaped domes and knolls, protruding through the granitoid rocks, which here show considerable variety in lithological habit. The rock is especially rich in labradorite, but diallage is also present. Zirkel has compared it with various European types,* and some from elsewhere. Through the courtesy of Professor W. A. Knight, of Laramie, the writer has received specimens of this gabbro, and it would at once be placed by one familiar with the labradorite rocks of the Adirondacks and Canada, in the anorthosites as the term is used in Canada and this country. Professor Knight has also forwarded a rock which he labels as the wall rock of the titaniferous ores. In thin section it is a most typical gabbro. †

Olivine gabbro would be a much more natural wall rock than

* See Volume VI., of the Survey, p. 107. Zirkel calls the granite a gray metamorphic one, rich in brown biotite (p. 58).

† These and other rocks from new districts in Wyoming have furnished the material for a series of petrographical notes by B. F. Hill, one of the writer's students. They are published in the SCHOOL OF MINES QUARTERLY, July, 1898.

granite and if it is the wall rock in some of the exposures, it would establish the kinship of the ore with the gabbro, a kinship that any one familiar with the ores of this type would at once believe and assume.

An analysis of the gabbro, given by Zirkel and Hague appears under V. below.

	I.	II.	III.		IV.	V.	VI.	VII.
SiO_2	0.76		Insol. 2.15		71.54	52.14		1.21
TiO_2	23.49	23.32	23.18				49.47	22.43
Fe_2O_3	45.03		48.97		2.45	3.26		47.21
FeO	17.96		24.55					25.80
Al_2O_3	3.98				15.04	29.17		
Cr_2O_3	2.45							
Mn_2O_3	1.53							
CaO	1.11				1.40	10.80		
MgO	1.56				0.27	0.76		
ZnO	0.47							
K_2O					5.27	0.98		
Na_2O					3.15	3.02		
P	tr.			P_2O_5	0.07			
S	1.44		0.03	Loss ign.	0.90	0.58		1.14
Total	99.78		98.88		100.09	100.71		97.79
Fe	45.49	50.83	53.33				34.29	51.72

No. I. is by J. P. Carson from Hayden's Report, cited above.

No. II. is by O. D. Allen, for Arnold Hague, Iron Mountain ore.

No. III. is by R. H. Richards, for Arnold Hague, Iron Mountain ore.

No, IV. is by R. W. Woodward, for Arnold Hague, wall rock granite.

No. V. is by Wiedemann, for F. Zirkel, gabbro.

No. VI. is by R. W. Woodward, for Arnold Hague, coarse granular ore from south of Iron Mountain.

No. VII. Analyst not given. Bulletin 14, Wyoming Experiment Station, 177. Other ingredients not determined.

The analyses exhibit a surprising uniformity in the amount of TiO_2 in the first three samples. Although taken at two widely separated intervals and by different observers they do not vary much beyond the limits of error of duplicate analyses. The main mass or ore may be expected to run about 23% in TiO_2. The iron percentage is more variable and this makes the constancy of the TiO_2 the more remarkable as a study and plotting of analyses by the writer shows the great sympathy between the TiO_2 and FeO. Analysis IV is from a sample taken south of the main mass.

Another striking feature of I. is the high Al_2O_3 as compared with

the SiO_2, which leads to the inference that spinel is present in the ore. It corroborates in a certain degree the kinship with the anorthosites, which of all igneous rocks are the ones richest in alumina. A spinel would explain the mineralogical affinities of the CaO, and MgO, which, otherwise, in the absence of SiO_2 are anomalous. The small percentage of zinc is doubtless in combination with the sulphur, but its presence furnishes an interesting parallel with the ore of Cumberland Hill, R. I.

South America—Brazil.

O. A. Derby has described some peculiar masses of titaniferous magnetite from the district of Jacupiranga, in the province of São Paulo, Brazil.* The ores occur in a series of low hills, which rise from the low plains of the coast near the lower course of the Ribeira or Iguape river. The oldest rocks are a series of metamorphosed clay slates, with occasional quartzites and rarely limestone. They are cut by numerous eruptions of granite, and are probably of Cambrian age. Between the small Jacupiranga river and the larger Ribeira is a divide consisting of gneiss and granite, flanked on either side by the schists. The divide is penetrated by a great variety of intruded dikes, hicwh represent the following types: "orthoclase-pyroxene, orthoclase-nepheline and plagioclase-nepheline rocks, nephelinites, teschenites, vogesites, basalts, etc." In the ore district proper, "the predominant rock, * * *, is a dark brown or black schist, in inclined layers, with an abundance of mica flakes along the division planes, which give it the aspect of a mica schist. Sections from the inner portion of one of these mica-covered slabs, * * *, show the rock to be composed almost exclusively of irregular grains of violet-colored titaniferous pyroxene, with, as accessories, an abundance of iron minerals (magnetite and titaniferous iron), rare grains of perofskite, and milky white grains, in part apatite, in part a zeolitized silicate. No mica can be seen in these sections," but elsewhere Dr. Derby demonstrates its derivation from the pyroxene. In many places the iron minerals become the essential minerals and the pyroxene if present is contained in a mass of magnetite, like phenocrysts in a ground mass, and strongly suggesting some of

* Orville A. Derby. On the Magnetic Ore Districts of Jacupiranga and Ipanema, São Paulo, Brazil, *Amer. Jour. Science*, April, 1891, p. 311.

the structures of meteorites. Dr. Derby gives a cut from a photo-micrograph, that is very similar to slides of the Adirondack ores.* The pyroxenes of the latter are not, however, violet colored, and brown hornblende, olivine and garnet appear in frequent association.

The Brazilian pyroxene-magnetite rock may develop elsewhere into a pyroxene-nepheline aggregate, with greatly diminished iron minerals, but with perofskite, apatite and biotite remaining constant and with olivine as a frequent accessory. Derby hesitates to call this variable rock pyroxenite, and suggests "jacupirangite," which he defines as follows: "The rocks included under this title are allied to the nepheline-bearing series and present the various types of pure magnetite, magnetite with accessory pyroxene, pyroxene with accessory magnetite, and pyroxene and nepheline, with biotite and olivine as accessory or (in the case of the former at least) essential elements. All these types are most intimately associated as parts of the same mass, and the gradual passage from one to the other has been most satisfactorily proven. The most constant and characteristic element is a violet, titaniferous pyroxene.

In limestone, close to the contact with an intruded mass of jacupirangite, the interesting mineral, consisting of oxide of zirconium, was found, which was described by Hussak as brazilite,† but it also appears as an accessory in the jacupirangite.

The district of Ipanema which is likewise described by Derby, lies on the opposite side of the Serra de Mar, and 150 kilometers from the locality of Jacupiranga. In general, the geological relations of the magnetite are similar, it being associated with igneous dikes, but it contains no titanium and, therefore, is not further discussed in this connection.

(To be concluded).

* The cut appears on p. 313 of Derby's paper. The writer may add that many conversations with Dr. Derby about these ores, in 1890, during the latter's visit to the United States and a study of the thin sections in question, largely led to the awakening of his interest in the analogous titaniferous ores of the Adirondacks.

† This is called orthite on p. 315 of Derby's paper, the identification having not then been made. See E. Hussak, Ueber Brazilite. Neues Jahrbuch—1892. II. 141, Hussak supposed it to be a tantaloniobate, but its true composition was shown to be zirconia by C. W. Bloomstrand, *Idem*, 1893. I. 89. This demonstrated its identity with baddeleyite described by L. Fletcher in *Nature*, Oct. 27, 1892—and the name baddeleyite, therefore, took precedence.

NOTES ON A SET OF ROCKS FROM WYOMING, COLLECTED BY PROFESSOR WILBUR C. KNIGHT, OF THE UNIVERSITY OF WYOMING.

By BENJ. F. HILL.

In some respects the geology of Wyoming has been studied in a comparatively thorough manner, as for instance with regard to its coal fields and tertiary lake basins, but the petrography of its eruptive rocks largely remains for the future. A few places, such as the Yellowstone Park,* the Crandall Basin,† the Devil's Tower,‡ the Leucite Hills, § and scattered points along the fortieth parallel have received careful attention, but numerous areas still remain, and the following notes have been prepared with a view of throwing some light upon them.

There is a great region embracing the country contiguous to the Wind River Mountains, the Shoshone Mountains, the Big Horn Mountains, the Owl Creek Mountains and the northwestern part of the state, including portions of the Black Hills, about whose petrography little has been published.

The following notes are based upon a series of rocks collected by Professor Wilbur C. Knight, of the University of Wyoming, which were sent by him to Professor Kemp for study and classification. They were turned over to the writer by Professor Kemp, but all the results obtained were verified by him.

The rocks comprise a set of fifty specimens and present a good variety of types. They are from localities in diverse parts of the State, but most of them are from the north rather than the south.

* J. P. Iddings. "Obsidian Cliff." 7th Ann. Rept. Dir. U. S. Geol. Survey, 249–295, 1888. "Eruptive Rocks of Electric Peak and Sepulchre Mountain." 12th Idem., 569–664, 1891. "Absarokite-Shoshonite-Banakite Series," Journal of Geology. Vol. III., pp. 935–959.

† J. P. Iddings. "A Dissected Volcano of Crandall Basin, Wyoming." Jour. of Geol., Vol. I., pp. 606–611.

‡ L. V. Pirsson. "On Some Phonolite Rocks from the Black Hills." Am Jour. Sci., 3d Series 47, page 341.

§ S. F. Emmons. Fortieth Parallel Survey, Vol. II., p. 236.

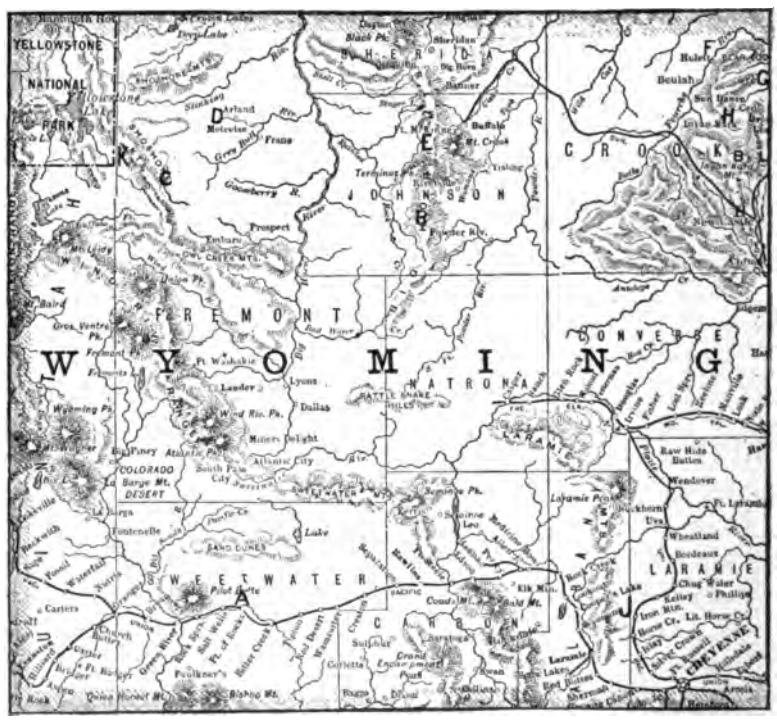
F. Zirkel. Idem., Vol. II., Microscopic Petrography, page 260.

J. F. Kemp. "The Leucite Hills of Wyoming." Bull. Geol. Soc. Am., VIII., 169–182.

Whitman Cross. "Igneous Rocks of the Leucite Hills and Pilot Butte, Wyoming." Am. Jour. Sci., 4th Series, IV., pp. 115–141.

One disadvantage encountered was the decomposed state of part of the material, but this, however, was unavoidable, as in a number of instances the specimens had been collected from drift and stream boulders.

In addition to Professor Knight's set the writer examined some rock specimens presented to Professor Kemp by Mr. A. A. Anderson. They were collected by Mr. Anderson on his ranch (P. O. Wise) just over the divide from the southeast corner of Yellowstone Park, and were taken from dikes cutting the Cretaceous



sediments. Macroscopically they are dense black basaltic-looking rocks, with augite crystals plainly visible. Under the microscope they show a somewhat ophitic texture. Plagioclase, pyroxene, olivine and magnetite are present. The rock undoubtedly belongs to the group of igneous rocks in the eastern part of Yellowstone Park described by Iddings under the name shoshonite. This example seems to be free from leucite. The relation of the rocks might be expected from their close geographical correspondence.

The first of Professor Knight's series studied were from Black Rock Butte, Sweetwater County, in the southwestern portion of the State (*A* on the sketch map of Wyoming). The exact location of Black Rock Butte is fifteen miles north of Almond Postoffice, on the Union Pacific Railroad, and six miles northwest of Orenda Butte. It is one of the outlying masses of eruptive rock in the Leucite Hills region. It is an overflow that has pierced the Laramie Cretaceous, and forms a precipitous mass rising nearly seven hundred feet above the surrounding country. The eroded and broken rock from the sides forms a rough, but gentle slope midway up the butte, above which the sides are perpendicular, and, so far as known, inaccessible. The top is flat. This being only six miles from Orenda Butte, the rock should resemble the peculiar variety orendite recently described by Cross.

The rock from Black Rock Butte has already been described by Professor Kemp in his paper on the Leucite Hills. He found it to be of the general type of the neighboring flows, but while containing the rods of orthoclase and the peculiar yellow biotite (later shown to be phlogopite by Dr. Cross) it had few leucites and unusually large augites for this locality. Professor Kemp gives a figure drawn from a photo-micrograph.*

One specimen was collected from Cloud's Peak, Johnson County (*B* on map). This locality is in the northern central part of the State, in the Big Horn Mountains. The rock came from the crest of the range, 12,800 feet above tide, and is typical of the mountain. Though somewhat decomposed, under the microscope it shows fine shearing effects. The rock is evidently a granite changed into a gneiss. Large othoclases, quartz and biotite are present, and the interstices between the the large crystals are filled with crushed material, which in some instances seems to flow around the phenocrysts like the flow structure in effusive rocks.

Eight specimens were obtained from the headwaters of the Wood River, which rises in the Shoshone Mountains (*C* on map), in Big Horn County, and flows east and north and reunites with other streams to form the Gray Bull River. At the head of the river there is a very promising mining camp, and the eruptives

* The above observations are corroborated by the specimens in the collection of Professor Knight. Many phenocysts have been destroyed by decay, but the rod-like orthoclases are still recognizable in the ground-mass, and the augite and biotite may still be determined. A few small leucites were noted.

come from the mineralized region. All these specimens were taken from boulders in or along the stream. With one exception they are andesites and dacites and exhibit beautiful and typical examples of these rocks. The andesites contain varying amounts of augite and hornblende, with enough of the latter mineral to cause them, in some instances, to be classed as hornblende andesite. This mineral exhibits sections along and across the prism, which latter show fine cleavage lines. The variety is common green hornblende. The plagioclose is in some instances fresh and furnished exact measurement, and by the Michel Levy method was determined to be audesine. Another variety, only a few examples of which were seen, is nearer labradorite.

Some of the slides showed good developments of chlorite and epidote mostly from the alterations of the hornblende. The dacites are two in number and are almost identical with the andesites except for the presence of quartz. This occurs in considerable amounts. Some of the crystals show fine corrosion phenomena, and almost all are rounded by resorption. Magnetite is present in small quantities. One rock from this district is neither an andesite nor a dacite, but a badly weathered and much sheared mechanical rock, probably a conglomerate. The quartz is fresh, but large amounts of clay and kaolin are present.

Meteetse County lies to the north of the Wood River (*D* on map). This is a small stream which rises in the heart of a large area of volcanic breccia and conglomerates, flows eastward and joins the Grey Bull River some miles below Meteetse Postoffice. The volcanic breccia rests upon upturned Fox Hills Cretaceous rocks that have an elevation of less than 7,000 feet, while the breccia rises to a height of 12,000. It is to some extent stratified and there are occasional logs of agatized wood scattered through the beds. All the specimens were taken from the creek bed and were originally derived from the breccia. They comprise another beautiful set of augite and subordinate hornblende andesites, some of which are perfectly typical cases of these rocks. The groundmass is in most cases made up of rods of feldspar and has a fine felsitic texture. The phenocrysts are augites, plagioclase, hornblende and magnetite. The augite is generally unaltered and many beautiful twins occur. Zonal feldspars are common and they contain inclusions. Olivine is present in a few cases and it forms the center of serpentinous alteration products. In one

slightly altered specimen, small geodes filled with secondary quartz were present. Two of these were cut across in the section and gave beautiful spherulitic effects under crossed nicols. The Meteetse feldspars showed on measurement that they are plagioclases of the andesine and labradorite varieties. The andesine was the predominant species.

There were four specimens taken from the country rock at Ten Sleep Lake (*E* on map), Big Horn county. They, together with the rock from Cloud's Peak, are representative of the Archæan exposure in the Big Horn Mountains. The range rises to an elevation of 13,000 feet, and is made up of rough and rugged peaks, deep canyons, and valleys covered with forests of spruce and pine. The only additional eruptive rocks observed were numerous trap dikes but no specimens were gathered. Two of the rocks are typical granites made up of quartz, orthoclase and biotite, but both contain considerable amounts of accessory hornblende. In the other two rocks hornblende is the chief constituent, they being amphibolites or hornblende schists. One contains appreciable quantities of titanite.

There were several rocks from the Bear Lodge Mountains near Warren's Peak (*F* on map). These mountains extend from Sun Dance north and west to the Belle Fourche River, a distance of 25 or 30 miles. The range is a simple anticlinal fold, its highest point having an elevation of about 6,500 feet. The erosion has been very heavy, so that at the present time, the range is made up of Carboniferous, Silurian and Cambrian strata, which are flanked by the Mesozoic series. The eruptives are associated with Paleozoic rocks only, and are in dikes and sheets. The rocks are decomposed, but enough remains to recognize two good trachytes and a phonolite. The phonolite shows hexagonal cross-sections of nepheline crystals.

Welcome (*G* on map) is a small mining camp in Crook County, near the South Dakota line, and is at the western foot of the Black Hills uplift. Associated with dikes, there are quartz veins, that assay high in gold. These eruptives, as those from Bear Lodge, cut through Cambrian and Silurian rocks. The rock from a dike two miles west of the town of Welcome, proved on study to be porphyritic, with felsitic groundmass, having phenocrysts of augite and hornblende with some epidote. The plagioclastic feldspar determined the rock to be an augite andesite.

The rocks collected were noted by Professor Knight at Welcome, as being in dikes and sheets. One is a typical granite

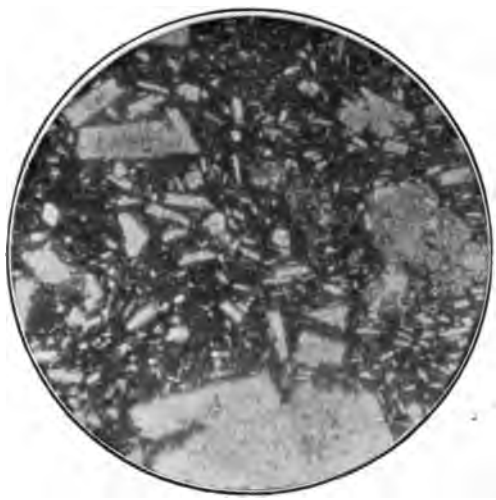


FIG. 1. Andesite, Wood River.

whose dark silicates have been weathered to limonite. One badly decomposed rock shows little else than epidote. Another is a basalt

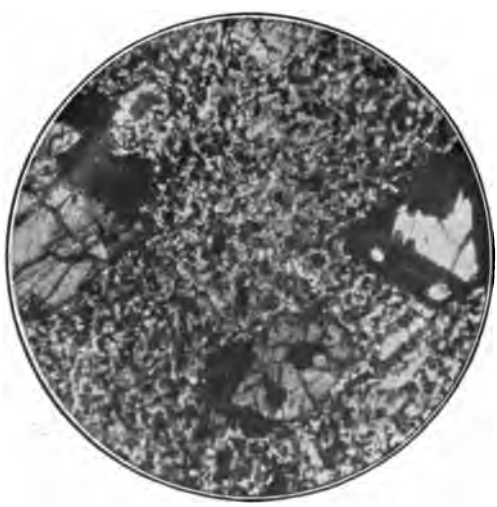


FIG. 2. Phonolite, Bear Lodge.

and contains plagioclase and augite, with magnetite and apatite as accessories. The augite forms eyes or masses of small crystals aggregated together. An exceptionally fine gabbro from the same

locality contained olivine, augite, biotite, magnetite and some remarkable apatites. These latter are colorless and have a relatively

FIG. 3. Gabbro, Welcome.

high relief when compared with surrounding minerals. As usual in rocks of the gabbro family the apatites occur in short thick col-

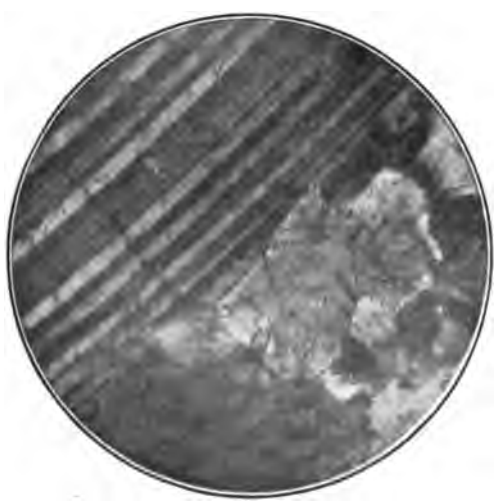


FIG. 4. Anorthosite, Iron Mountain (crossed Nichols.).

umns, exhibiting in sections parallel to the base hexagonal figures, and in those parallel to the principal section, rectangular figures. (See Fig. 3.)

One mile southeast of Welcome is a sheet of badly decomposed trachyte, whose characteristic groundmass and phenocrysts can still be distinguished. A piece of dike rock from the Interocean mine showed nothing recognizable but a remarkably large percentage of iron pyrites.

From Sun Dance Mountain (*H* on map) in the same general region and only a few miles from the Dakota line is a well preserved trachytic tuff. Sun Dance Mountain is an oblong mass of rock about a mile in length and a quarter of a mile in width. It has an elevation of over 1000 feet above the surrounding country. It has been suggested that it is a laccolith, but observations do not confirm the theory.

The above concludes the specimens from the northern portion of the State, as the others were gathered in the southeastern section, in Laramie and Albany Counties. Plumbago Canyon is in Albany County, 25 miles north of Laramie (*I* on map). From this locality we have two marbles and a granite. The marbles are found in upturned carboniferous rocks flanking the west side of the Laramie Mountains. One of the marbles is decomposed and contains large quantities of serpentine, and the other, though fresh, contains some tremolite. The granite is a handsome rock and shows fine shearing effects in its feldspars.

From three miles west of Iron Mountain (*O* on map) we have a sheared rock, probably a former granite, but now a mica schist. The country rock two miles west of Iron Mountain is an olivine-bearing amphibolite, with which is associated an olivine gabbro. The rock from the east wall of the Iron Mountain mine is a gabbro, as reported by the Fortieth Parallel Survey. It is made up mostly of labradorite and presents a striking resemblance to the Adirondack anorthosite. Some of the feldspars are untwinned, an interesting but not uncommon circumstance. The anorthosite is associated with titaniferous magnetites, another point of close resemblance between it and the Adirondack rock.

Several photomicrographs have been prepared to illustrate the interesting and typical varieties of rock above mentioned. (Figs. 1, 2, 3 and 4.) The photograph of Black Rock Butte was reproduced from one presented by Professor Knight to Professor Kemp.

In conclusion the writer wishes to acknowledge his indebtedness to Professor Knight for geographical and stratigraphical notes bearing on the rock specimens, and to Professor Kemp for suggestions and assistance in preparing his material.

THE PARADOX OF THE PANTHEON. I.

A Study in Ancient Roman Vault Construction.

A. D. F. HAMLIN.

I.

The technical methods and processes employed in ancient Roman construction constitute an interesting branch of the history of building. The Romans of the Imperial age admired bigness and magnificence, but were at the same time intensely practical, driving straight to the goal they sought by the most direct path they could find. They were mechanically inventive, economical in some directions but supremely lavish in others; bold in their conceptions and full of resource in executing them, they were the greatest engineers of their time, and of all times previous to the present age of exact scientific calculation. In many ways their military roads, aqueducts and bridges, and in a qualitative sense the engineering of their great buildings, equalled the great achievements of our own day.

Roman architecture, which has often been decried by the literary critics of art as lacking in originality, was in reality full of innovations upon the Greek prototypes from which it derived its decorative elements, while on the structural side it was an absolutely new and original development of the builder's art. It is to the Romans that we owe the groined vault and dome—the noblest of all forms of ceilings. This is not saying that they had never been used before the Romans employed them. Indeed, we know that they came to Rome from Asia in the first instance, but it was the Romans who first realized their artistic value and developed their architectural possibilities. By these means they gave to their buildings effects of unencumbered spaciousness impossible with any combination of piers and columns, and assured to their great temples and thermæ a duration and freedom from danger of destruction by fire incompatible with wooden-roofed architecture.* Greek buildings remain to our day only as roofless ruins. The stupendous monuments of Egypt, rivalling those of Rome in magnitude, consist chiefly of open courts and colonnades, with hypostyle halls which, though roofed with stone, are encumbered by

* See my *History of Architecture*, p. 82 (Longmans, N. Y.).

massive columns so closely set that in the greatest of them all—the Great Hall at Karnak—the broadest aisle is less than 20 feet wide in the clear, and not over 80 feet high. Contrasting with these dimensions, the tepidarium of the Baths of Diocletian (now the church of Santa Maria degli Angeli) at Rome has an unencumbered floor space of 340 by 87 feet with a groined vault 90 feet high; while the Pantheon is 142 feet in diameter, and the circular opening at the summit of its colossal dome is 140 feet above the pavement. Such vast spaces under such lofty ceilings had never been dreamed of until the Romans conceived and executed them.

The constructive methods by which these stupendous achievements were effected are worthy of careful study. M. Auguste Choisy has bestowed upon them much valuable research, not wholly unmixed with imagination, in his well-known work *L'Art de bâtir chez les Romains*, and Professor Durm, of Carlsruhe, has added to these investigations in his treatise *Die Baukunst der Römer* in the great Darmstadt series entitled—with a touch of Teutonic humor, perhaps—"Handbuch der Architektur." The late Professor Parker, of Oxford, attempted to evolve a chronological system of the various forms of brick and stone masonry in the walls of Rome; and many Italian scholars, notably Lanciani, have contributed, and are constantly adding, to our knowledge of the structural details of Roman buildings. In many of these various writings the Roman methods of erecting huge vaults receive attention, but the subject still awaits careful and concentrated investigation by an expert, provided with the large capital and elaborate apparatus necessary for an examination in detail of the existing remains, complete or fragmentary, of vaulted buildings, and above all endowed with the discrimination which can distinguish between customary and exceptional, traditional and original, logical and accidental devices, forms, and methods. Such a systematic study of Roman vaulting has never yet been attempted; and in the most perfectly preserved and frequently visited of all Roman monuments, the Pantheon at Rome, the extraordinary contradiction between the construction and decoration of the magnificent dome, though it has been perfectly well known for a hundred and fifty years, has not only never been explained, but has hardly been discussed. Having myself in 1894 observed certain facts which suggested a somewhat startling explanation of the paradox, and having for five years awaited in vain, or at least failed to meet with,

any other theory or explanation from archæologists in Italy or elsewhere, I venture now to set forth my theory and the reasons which have led me to adopt it as correct in the hope that it may elicit from those who are in a position to examine the vault of the Pantheon and other examples of Roman vaulting, either a convincing refutation or a positive confirmation. In order to present this theory it will be necessary first to discuss at some length the general methods of Roman construction.

II.

The whole Roman system of constructive design was based on the use of concrete. The Egyptian and Greek architectures were essentially architectures of stone, whatever their primary origins in buildings of mud, rubble or wood. They depended for their forms, and decoration on the axe and chisel, on the quarrying, transportation, squaring, hoisting, placing, dressing and carving of huge blocks of granite, limestone or marble. The erection of buildings out of these materials was a work of infinite labor, slow and tedious, time-consuming and enormously expensive. A single temple, or at most two or three, were the work of a reign or a lifetime, and absorbed the resources of a kingdom or empire, not merely in money but in artists and artificers. When, under the early emperors, Rome became a truly imperial power, architecture received an extraordinary impulse. Not only in the capital, with the immense resources acquired by conquest, were innumerable edifices undertaken of the first magnitude—temples, basilicas, fora, circuses, theatres, colonnades, triumphal arches and administrative buildings—but the remotest provinces were embellished with monuments and temples, gates and amphitheatres and tombs, to serve as the ever-present symbols of the Roman might and splendor. Manifestly, with such an unexampled activity in building, extended over so wide an area, the slow processes of Greek or Egyptian stone-construction were out of the question. The difficulties of the problem were enormous; but the practical Romans found their solution in the use of concrete for the masses of their masonry and of the vaults and domes with which they roofed these buildings. Every process and device which they adopted in their erection was primarily conceived with a view to making available the physical resources of vast hordes of slaves and of soldiers, *i. e.*, of unskilled laborers in great numbers; and to using the relatively

limited artistic resources of the empire in such a way as to make a minimum of original design serve for a maximum of buildings. To this end concrete, which can be mixed, carried, dumped and rammed by the most ignorant laborers, formed the greater part of the walls, piers and vaults; brick and stone were used only for the facings, and thus called for a minimum of skilled mason-work, and the decoration was a skin or veneer, of stucco, marble or mosaic, worked upon traditional lines not requiring the constant exercies of the highest originality in design, and who could travel from building to building as each in turn required their services.

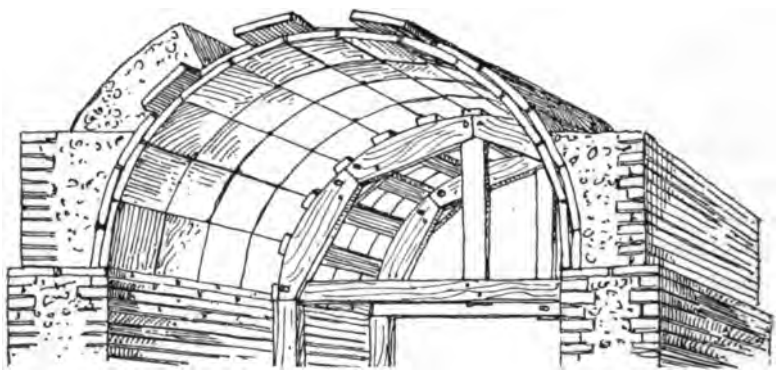


FIG. 1.

This is, indeed, the prevalent modern system of building; to us it seems the most natural procedure in the world. But it was first worked out by the Romans, with whom it was a new conception, and applied to buildings of the most extraordinary variety and of the most complex design, in which the Roman freedom and ingenuity in planning were conspicuously displayed. The dominant note in this complex and varied architecture, at least on the constructive side, was that of practical common sense. To avoid expense and loss of time, as well as to get over the difficulty of finding capable carpenters, complete timber centerings were often dispensed with in building vaults. To support the enormous weight of the heavy concrete vaulting while it was setting would have involved a massiveness of timber construction for centerings which was deemed extravagant. Two methods were adopted to avoid this. Sometimes over a very light centering of wood, covered not with boards but with slats a couple of feet apart, there was built a thin vault of two-foot tiles laid flat in strong cement.

Smaller tiles breaking joint over these completed a remarkably strong elastic shell, which when loaded up to the haunches with concrete, was quite sufficient to carry the weight of the concrete afterwards dumped upon its upper portion to any reasonable thickness (Fig. 1). In other words, the tiles, forming a sort of Guastavino vault, constituted the real and permanent cementing for the concrete vault. The second process, used in the larger vaults, was more complex. Centerings were first set up for a series of ribs, which were constructed of tiles in a sort of cellular formation by turning two or three ribs, one brick wide, a foot or so apart, with large two-foot tiles at intervals to bind them together (Fig. 2). Other cen-

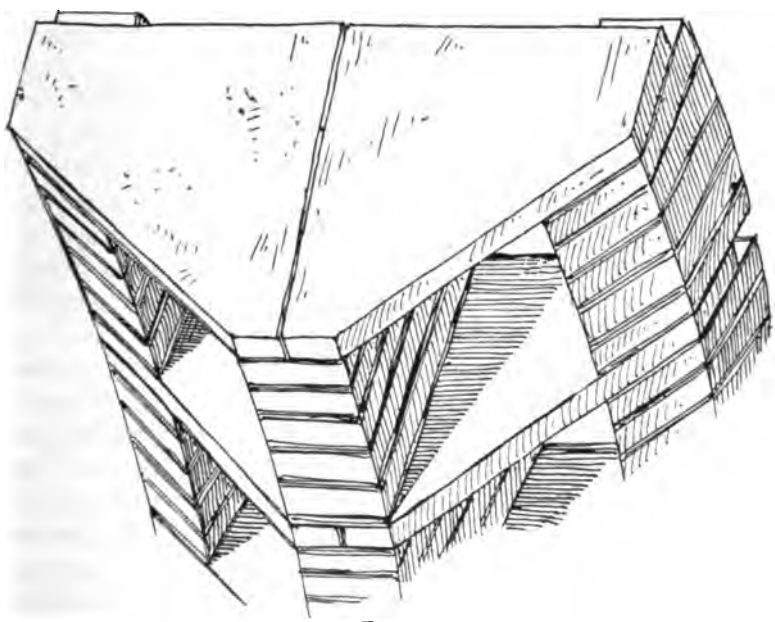


FIG. 2.

terings, fixed or movable, were set up between these, and upon them the concrete fillings were poured and rammed. But as the fillings, starting from the spring and growing in height a foot or two daily, set and hardened rapidly, they formed as it were monolithic lintels between the ribs, bracing them against any possible lateral overturning, and at the same time taking on themselves a part of the weight of the next portion of filling, and opposing resistance to any deformation of the wooden centerings as the load crept up to-

wards the crown. By this means the centering was made to carry a nearly constant, and not a constantly increasing load; namely, that of the newly-laid wet concrete only, and not quite the whole of that; the remainder was carried by the lower portion already hardened, which was in turn borne entirely by the ribs.

It has been claimed also for the Romans that they anticipated the Gothic invention of ribbed vaults, in which the ribs being first built, themselves serve as supports for the centerings under the fillings; these centerings being hung from the ribs much as we hang from our steel beams the centerings for the flat brick arches between them. This is not an impossible supposition, and is in harmony with what we know of Roman ingenuity and practical sense in building. But it is not likely that this procedure was followed in the larger vaults. The brick ribs existing in such extant vaults of large size as have been examined are too light and flimsy to have ever carried the combined weight of the suspended centerings for the fillings and of the concrete loaded upon these.

This failure to carry to their logical conclusion in large vaults the suggested possibilities of the system of ribbed construction—a system which was destined after the lapse of a thousand years to become one of the most important features of Gothic vault-building—illustrates the limitations of the Roman practice. The logic of the Roman builders failed them in its higher developments. They carried their principles so far and no farther. Beyond a certain point their admirable methods degenerated into unthinking routine, and the logical reasoning out of which they had grown was travestied in the most absurd and unaccountable fashion. In many vaults may be seen ribs which could not possibly have served any useful purpose, and which must have been built at the same time with the fillings in which they are buried, by workmen ignorant of their intended function and blindly following tradition instead of reason. Thus in Fig. 3 (so-called Temple of Minerva Medica) the minor ribs end nowhere, and it is difficult to understand either their function or that of the little arches which cut them in two a little over half-way up. Nearly every large building of the third and fourth centuries shows similar solecisms, and even the Pantheon, dating from the early part of the second century, is full of them. Lanciani declares that the beautifully executed discharging-arches which are so noticeable in the upper part of the exterior brick facing of that temple are only one brick deep and serve no constructive

purpose whatever. One would imagine that they would have been carried through the whole thickness of the wall, thus concentrating the pressure of the dome upon the solid piers between the niches;

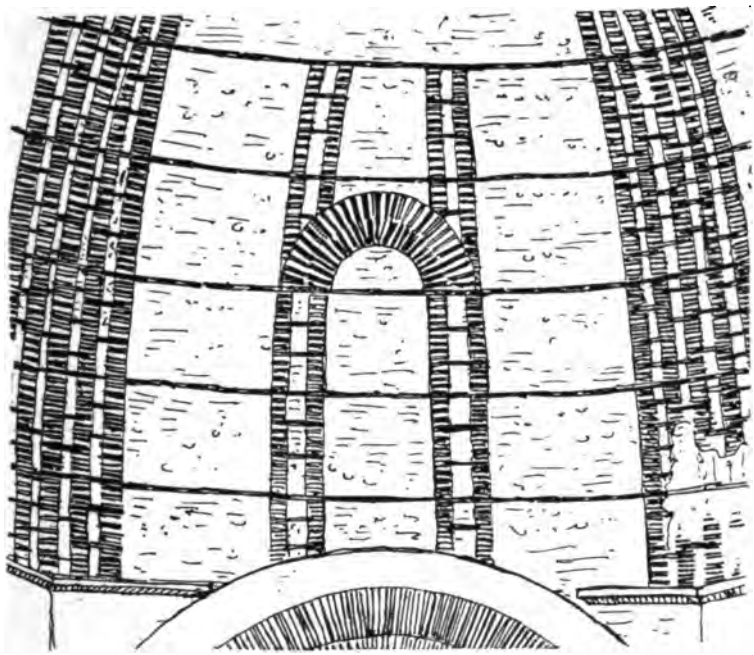


FIG. 3.

but Professor Lanciani has assured me that this is not the case, this function being discharged by the lower tier of arches in the dome itself.

This introductory survey of the Roman practice in building is necessary to the discussion of what may rightly be called the paradox of the dome of the Pantheon. In this dome the constructive ingenuity of the Romans appears highly developed and yet associated with the most extraordinary disregard alike of that economy of means and labor which characterizes Roman building in many of its phases and of the logical connection which in most great works of architecture exists between the structural framework and the decorative dress of a building. In the dome of the Pantheon these are not merely independent or even discrepant, but absolutely contradictory and this contradiction forms the subject of the next paper.

(To be continued.)

Contribution from the Havemeyer Laboratories of Columbia Uinversity.

ON THE SEPARATION AND DETERMINATION OF ARSENIC AND ANTIMONY IN ORES.

BY O. C. BECK AND H. FISHER.

This work was undertaken with the idea of comparing the different known methods, and determining which was the shortest and at the same time the most accurate.

The ore used was an artificial mixture of a native oxide of antimony and a mispickel.

DECOMPOSITION OF THE ORE.

1. This was effected by treating with hydrochloric, nitric and tartaric acids;* any residue remaining was leached with ammonium polysulphide. The solution was then diluted and the arsenic and antimony precipitated with hydrogen sulphide. These sulphides were then dissolved in hydrochloric acid and potassium chlorate and the arsenic and antimony separated by either of the methods which will be given in that section.

2. *Decomposition by Means of Caustic Soda* (H. Rose).† About 5 gm. ore was fused with approximately eight times its weight of sodium hydrate, with a little sodium carbonate and nitrate in an iron dish until completely decomposed. The fusion was allowed to cool and then leached with boiling water and allowed to stand for twenty-four hours with one-third its volume of alcohol. The solution was then filtered and the residue washed, first with alcohol diluted with twice its volume of water, then with a mixture of equal volumes, and finally with a mixture of three volumes of alcohol to one volume of water. To each of these alcoholic solutions a few drops of sodium carbonate solution was added. This treatment converts the arsenic and antimony respectively into soluble sodium arsenate and insoluble sodium metantimonate.

3. *Decomposition by Means of Sulphur and Sodium Carbonate*—(H. Rose).‡ About .5 gm. ore was fused with three parts of sodium potassium carbonate and three parts of sulphur, the melt

* Cairn's Quantitative Analysis, 3d edn, p. 232.

† Fresenius' Quantitative Analysis, 10th Am. Edn., p. 572.

‡ Cairns' Quant. Analysis, 3d edn., p. 232.

leached with hot water and filtered from the insoluble residue. This gives the soluble sulpharsenate and sulphantimonate from which the arsenic and antimony are precipitated by acidifying with dilute sulphuric acid. This precipitate was dissolved in hydrochloric acid and potassium chlorate, and the arsenic and antimony separated.

4. *Decomposition by Hydrochloric Acid and Potassium Chlorate*—(Pattinson * and Fischer †). From .5 to 3 grams of ore depending upon the amount of arsenic present, was dissolved in 30 c.c. conc. hydrochloric acid and 12 c.c. water and about five times its weight of potassium chlorate added, heated on the water bath until the ore was dissolved and the chlorine driven off. If the potassium chlorate is first placed in the beaker so as to cover the bottom, then the weighed ore placed on this and more chlorate added sufficient to cover the ore and the acid and water then added, the ore goes into solution more readily than if it is placed directly on the bottom.

5. *Fusion with Sodium Carbonate and Nitrate*—(Pearce ‡). About .35 grm. ore was mixed with about ten times its weight of a mixture of one part sodium carbonate to two parts potassium nitrate in an iron dish and a cover of the same mixture placed over the whole. The contents were gradually heated to fusion and kept in that state for five minutes. The fused mass was cooled, dissolved in water, digested at a boiling temperature for a few minutes, the residue filtered off and washed. This method was modified as follows: Instead of fusing the ore directly with the carbonate and nitrate mixture, it was first treated on the water bath in a porcelain crucible with fuming nitric acid and taken to dryness. This treatment was repeated three times. The mass was then mixed with the carbonate and nitrate and treated as described above.

Another modification of this method was tried. A layer of potassium nitrate was fused on the bottom and sides of the iron dish and on this the mixture of ore and carbonate and nitrate was placed, and the method carried out as before.

Separation of the Arsenic and Antimony.

1. *Fischer Distillation Method.*—The solution of the ore (see 4) or the sulphides dissolved in hydrochloric acid and potassium

* Journal Society of Chemical Industry, Vol. 17, p. 211.

† Berichte, XIII., p. 1778.

‡ Chemical News, Vol. 48, p. 85.

chlorate (see 3) was placed in a distilling flask connected with a Liebig condenser which had a delivery tube dipping into a small amount of water contained in a beaker. About 5 grams of ferrous sulphate were added, and the contents brought up to 150 c.c. with 30 per cent. hydrochloric acid, and distilled till only 35 c.c. of the solution remained. The flask was then cooled, the contents again brought up to 150 c.c. with 30 per cent. acid and again distilled. This was repeated till the distillate showed no traces of arsenic when tested with hydrogen sulphide. This required six distillations. The arsenic in the distillate and the antimony remaining in the flask were precipitated with hydrogen sulphide.

2. *Pattinson Method.*—The solution (see 4) was filtered on asbestos and the residue washed thoroughly with a solution of 30 c.c. hydrochloric acid and 12 c.c. water. The arsenic in the filtrate was then reduced by adding small portions of stannous chloride till the solution was colorless, then a slight excess of the chloride was added. Hydrogen sulphide was then immediately passed into the cold solution till saturated. As long as the solution is so strongly acid that it has a specific gravity of 1.16–1.17 arsenious sulphide precipitates free from the sulphides of lead, cadmium, tin, antimony and bismuth. The solution is stirred and the precipitate settles rapidly, it is then filtered off, washed with a solution of five parts of concentrated hydrochloric acid to two parts of saturated hydrogen sulphide water and finally with water alone.

3. *Magnesium Ammonium Arsenate Separation.*—The precipitate of arsenic and antimony sulphides (see 3) was dissolved in hydrochloric acid and potassium chlorate, a small amount of tartaric acid added and ammonium hydrate till nearly alkaline. An excess of magnesia mixture was added and then about one-third of the volume of alcohol, and the solution finally made alkaline with ammonia. The solution was allowed to stand over night the precipitated magnesium ammonium arsenate filtered off washed with water containing ammonia till the washings showed no opalescence on acidifying with nitric acid and adding silver nitrate. The filtrate was evaporated to small bulk acidified with hydrochloric acid and the antimony precipitated with hydrogen sulphide.

Determination of the Arsenic.

1. *Pearce Method.*—To the filtrate (see 5) nitric acid was added till slightly acid and the solution boiled to expel carbon dioxide and

nitrous fumes. It was then neutralized with zinc oxide. A slight excess of the oxide was added and the solution allowed to stand over night to remove the last traces of acid. An excess of silver nitrate was added and the solution again allowed to stand over night to insure the complete precipitation of the arsenic. The precipitate was filtered, washed, dissolved in warm dilute nitric acid, and the solution titrated with standardized ammonium sulphocyanate using ferric alum as indicator. This titration was made in a 250 c.c. bottle provided with a tightly-fitting glass stopper, as it was found that the precipitate of silver sulphocyanate, held some of the silver arsenate, for after the solution showed a permanent red color after merely shaking, when the bottle was stoppered and well shaken, the color disappeared and it required another $\frac{1}{10}$ c.c. before the red color was permanent on further shaking.

2. *As Magnesium Ammonium Arsenate.*—The sulphide of arsenic, obtained by both the Fischer and Pattinson methods, was dissolved in fuming nitric acid, the nitrous fumes boiled off, the solution diluted, nearly neutralized with ammonia, cooled, one-third of its volume of 95% alcohol added, and magnesia mixture added slowly with stirring and a few drops more of ammonia, and the whole allowed to stand over night. The precipitate was then filtered on a Gooch crucible, washed with water containing alcohol and ammonia, dried by gradually heating the crucible over the flame and finally ignited, cooled and weighed as magnesium pyroarsenate.

3. *As Arsenious Sulphide.*—The precipitated sulphide of arsenic was filtered on a Gooch crucible, washed several times with 95% alcohol, once with absolute alcohol, several times with carbon disulphide, again with alcohol and finally dried in an air bath at 110° and weighed.

4. *Titration with Iodine.*—The arsenious sulphide together with the Gooch crucible was placed in a beaker with a small amount of conc. sulphuric acid. The beaker was placed in an air bath and gradually heated to 140–150°, being left uncovered so as to prevent the deposition of sulphur on the sides. As the sulphide dissolved the solution darkened and it was heated till the color disappeared and all sulphur dioxide, which would interfere with the subsequent titration, driven off. The solution was removed from the air bath, diluted and nearly neutralized with sodium carbonate, then sodium bicarbonate was added till the solution contained a slight excess, then titrated with a standardized N/10 iodine solution using starch as indicator.

DETERMINATION OF THE ANTIMONY.

1. *As Antimonious Sulphide.*—The antimonious sulphide obtained by (1) or (3) under "separation" was filtered on a weighed Gooch crucible, the precipitate washed with 95 % alcohol and then with carbon disulphide. The precipitate was then dried at 200° to constant weight.

2. *As Antimonious Antimonic Oxide.*—The antimonious sulphide was filtered on a Gooch crucible and treated with fuming nitric acid till no more sulphur was visible, when the mass was ignited to drive off the excess of nitric and sulphuric acids. A second method of converting the sulphide to the oxide is* to filter the sulphide on a small paper, wash with a 5 % solution of ammonium nitrate containing hydrogen sulphide. Dry the precipitate, separate it as much as possible from the paper and place in a small weighed porcelain crucible (50–70 c. c.). Spread the paper on a watch glass, wash it thoroughly with hot ammonium sulphide and then with boiling water. Evaporate the solution on a water bath to dryness, add fuming nitric acid till no more sulphur is visible, then ignite.

3. *Weller Method.*† *Titration of Liberated Iodine.*—The residue obtained by leaching the fusion of Rose's method (see (2) under "decomposition") which consisted of ferric oxide and sodium hydrogen metantimonate was dissolved in hydrochloric acid and potassium chlorate. The antimony was then precipitated as sulphide by means of hydrogen sulphide to separate it from the iron and filtered. It was then dissolved in hydrochloric acid and potassium chlorate, and the chlorine and oxides of chlorine driven off by heating on a water bath or by gently boiling. The solution was diluted to about 200–300 c. c., five grams of potassium iodide added and the iodine titrated with standard thiosulphate after adding starch solution. The thiosulphate solution used was standardized against copper and calculated to its equivalent in antimony.

4. *Mohr's Method.*—Titration with iodine‡. The sodium hydrogen metantimonate obtained by fusion was dissolved in hydrochloric acid and potassium chlorate, the antimony precipitated as sulphide and again dissolved as in the previous method. The an-

* Jannasch Practischer Leitfaden der Gerichtsanalyse, p. 145.

† Liebig's Annalen, 213, p. 364.

‡ Mohr's Titrirmetnode and Clarke. J. S. C. I., Vol. XV., p. 255.

timonic chloride was then reduced to antimonious chloride by means of a sulphurous acid. The excess of acid was then boiled out, one to two grams of tartaric acid added, the solution neutralized with sodium carbonate and 20–30 c.c. of a saturated solution of sodium bicarbonate added and the solution titrated at a bulk of 200–300 c.c. with standard N/10 iodine using starch as indicator.

The results obtained by these methods were as follows:

Arsenic.			
Pearce method,		15.83	15.94
Pearce method, nitric acid modification,		16.03	16.17
Pearce method, potassium nitrate modification,		16.18	16.37
Fischer method,		16.25	16.38
Pattenson method, iodine titration,		16.23	16.34
Pattenson method, magnesium pyroarsenate,		16.23	16.32
Pattenson method, arsenious sulphide,		16.69	16.94
Antimony.			
As antimonious sulphide,	18.74	18.91	Jannasch mod.
As antimonious antemonic oxide,	17.85	17.96	18.02
By Weller method,	18.12	18.09	18.16
By Mohr's method,	18.31	18.19	18.26

It will be seen from the table that the ordinary Pearce method and the nitric acid modification give slightly low results. This is probably due to a slight loss of arsenic by volatilization. The potassium nitrate method, while accurate, takes too long.

The Fischer distillation method gives good results but is also too long.

The Pattinson method is preferable to the other two on account of its accuracy and rapidity, especially when the sulphide is titrated with iodine. When the arsenic is weighed as sulphide the results are high, probably due to the impossibility of completely dissolving the sulphur out of the precipitate.

In regard to the antimony the sulphide also gives high results

The oxide gave slightly low results due to the unavoidable spattering on treating the sulphide with the nitric acid. Jannasch's modification while giving slightly higher results requires a longer time and introduces a large amount of sulphur which must all be oxidized before ignition.

The Weller and Mohr methods gave results which agreed closely.

The writers thank Dr. E. H. Miller for his kind assistance throughout this work.

SOME NOTES ON THE MINING PRACTICE OF THE WITWATERSRAND GOLDFIELDS, SOUTH AFRICAN REPUBLIC.*

By G. A. DENNY.

When it is considered that Witwatersrand as a goldfield dates back only to the year 1887, the development it has undergone in the intervening years must be granted to be quite unparalleled in the history of metalliferous mining. The reasons for its sudden expansion are due partly to certain features which are more or less singular to itself, and partly to the fact that in its methods has been incorporated all that modern science and the world's experience could teach.

The features which are more or less peculiar to the Witwatersrand are:

1. The particular nature of the gold occurrence.
2. The average width and grade of ore over very wide areas.
3. The permanence of the deposit to great depths.

Owing to the proved persistence of the above mentioned factors of grade, width and continuity, a new departure in metalliferous mining was inaugurated. This lay in regarding the Rand banket area as a deposit similar for purposes of calculation to a coal basin. In an unprospected block of ground lying adjacent to other working properties, the average width and grade of the said working properties were regarded as affording a practical basis for the estimation of the same value in connection with the contiguous but unworked block named. Hence the practice arose of ordering enormous reducing plants, to be erected and ready for working at such a time as it was estimated that from one and a-half to two years ore would be developed in readiness for mill supply.

The practical treatment of the banket showed that it was unusually free from those elements which render ores complex, such as zinc, arsenic, etc., and accordingly the application of a chemical treatment to the tailings after passing over amalgamated plates, was thought to be feasible. The process known as cyanide treatment was tried and adopted, as affording a satisfactory and economic solvent for the contained gold.

* Abstract of Transactions of Australian Institute of Mining Engineers, Vol. V.

The magnitude of the working operations on the Witwatersrand attracted expert men, engineers, chemists, etc., from all parts of the world, who put in practice the methods of mining and milling which were in vogue in the countries from whence they came. Thus, the best features of Australian and American methods were gradually blended into a combination suited, firstly, to a special object, which was maximum crushing duty per stamp and, secondly, to the most modern requirements of the various operations as culled from the world's experience.

The gold mining industry of Transvaal commands now the attention and interest of mining men, whether speculators, investors or technical in every country, and its rapid rise from an almost totally unknown territory to one that has become so well known and valuable as to be quite a bone of contention amongst European nations, is entirely due to the development of its mineral resources, and to the energy, capital and ability which have so planned the development that in a few years a strip of country 40 miles in length has risen to the ranks of the world's greatest gold producers. As an interesting illustration of the rapid increase in the Witwatersrand gold production I append the following table:

YEARLY RETURNS.

	Ozs.
1888	208,122
1889	369,577
1890	494,819
1891	729,238
1892	1,210,869
1893	1,478,477
1894	2,024,162
1895	2,277,685
1896	2,279,827
1897 (eleven months)	2,723,962

With these brief introductory remarks I shall pass on to the real subject matter in hand.

Mining.—The mining method of the Witwatersrand may be stated as identical in principle throughout the district, but differing in detail in accordance with the special features which given mines present, these being chiefly in the thickness of the reef, and the angle of dip. I have previously stated that the reef's average width

constitutes one of its most prominent features, and it may therefore appear contradictory to now state that one of the main differences of given mines is thickness of reef. My original statement, however, holds good in the large majority of instances, or in those which may be stated as forming the principal factor in the average. The instances I am now referring to are exceptional from the aspect of the concrete subject, but nevertheless exist to an appreciable extent on that portion of these goldfields known as the West Rand, in other words to those mines lying west of Johannesburg. Similarly in the matter of dip, there are no arbitrary limits within which the inclination of the reef is expressed, as in extreme cases the reef may be found very much under, or very much over, the average, which is taken at 35 degrees.

It may perhaps be well to begin this subject of Mining by classifying it into heads, each of which represents a particular process in the general function, and to discuss these separately. In pursuance of this plan I shall divide the subject of Mining as under:

Shafts.—In commencing this part of my subject I feel that it is necessary to introduce a few remarks upon the reefs which are mined in the Witwatersrand. The nature and genesis of these reefs have received very considerable attention at the hands of eminent men hailing from various parts of the world. The writer has also in a published work dealt with the subject at considerable length. The main conclusions arrived at are:

1. The reefs (banket bed) are beach deposits.
2. That their gold was deposited contemporaneously with the pebbles, pyrites, and detritus, which form its matrix.
3. That they are most probably of Devonian age.

In the Witwatersrand district, there are several series of banket reef, each series consisting of one or more beds. Of these the most important, and most ancient, is the Main reef series, from which almost the entire gold production of the Transvaal is obtained. The Main reef series consists really of a number of beds, or "reefs" as they are locally termed. In the Central Witwatersrand mines there are generally three reefs, namely:

1. Main reef.
2. Main reef leader.
3. South reef.

In the mines of the eastern section there is a reef known as the "North" reef, which underlies the Main reef, and again, as in the

Robinson mine, one known as the "middle" reef lying between the Main reef leader and the South reef.

The Main reef, so-called because of its prepondering width, is generally low-grade, that is, it contains from four to six dwts. of gold per ton by assay in the mine. Its value when placed in the mill bins, is probably from 25 to 35 per cent. lower than these figures, hence, under existing economic conditions, it is unpayable. At some points, as at the Robinson mine however, it contains payable gold, and is therefore mined proportionately with the South reef and the Main reef leader. The latter body varies in width from 18 inches to 3 feet, and is generally of payable grade.

The South reef varies from a few inches to four feet in width, with a probable average of two feet. It furnishes ore of the highest grade, excepting in the case of certain mines on the Eastern section of the Rand, which have both the North and the South reef. In these instances the South reef is generally unpayable, and the North reef is worked almost exclusively.

The reefs are, as a rule, much steeper at the outcrop than in depth. They are intersected, and displaced by ramifying dykes of diabase rock, which, although interfering with the reefs' continuity, seldom affect their value or width. The strike of the series is about east and west.

The distance, as between reef and reef, varies greatly in particular mines. In one case, for instance, the Main reef leader and Main reef are practically one, being divided only by a few inches of sandstone; in another case, and in the same mine, the distance may be 10 feet. Similarly, the distance from the Main reef leader to the South reef, which is only about 50 feet in the "Salisbury," is over 100 feet at some points in the "Robinson." Naturally the varying dips encountered have much to do with the horizontal distance as between reef and reef, but setting that factor aside, there is an important variation in the thickness of the sandstones between the interbedded reefs. The practical bearing of this relation is that whilst one level is sufficient when the reefs lie closely together, two are necessary when they are separated by an appreciable width of sandstone.

Having thus briefly stated the general features of the ore deposits, I now pass on to the matter under immediate consideration, namely "shafts." Almost without exception the shafts on the Witwatersrand are of rectangular section. Only in one or two

cases have circular shafts been adopted, and those in quite the "early days" of the industry's development. Many advantages are claimed for them by men who have experienced their use in connection with coal mining, but the fact that they have not come into any favor upon the fields argues a want of any particular merit from the metalliferous miner's standpoint.

Almost without exception the outcrop mines on these fields are worked by incline shafts, the number of which is determined by the length of outcrop which a given company holds. Should, for instance, a company's boundaries include 5,000 feet of outcrop, two shafts would be sunk at about 1,000 feet from the eastern and western boundaries respectively. The properties of the earlier formed companies are, however, much smaller in area than that instanced, as:

Wemmer, 1,500 feet on strike.
Salisbury, 900 feet on strike.
Ferriera, 1,645 feet on strike.

The shafts are usually so placed that their longer axis is in the direction of the strike of the beds. The usual size of an incline shaft is somewhere between the limits of 18 and 22 feet on the long side, and five to six feet on the shorter. An average size for an incline shaft, on an outcrop property, is 18 feet by 5½ feet. The shaft is usually divided into four compartments; two of which are used for hoisting broken ore, the third for sinking purposes, and the fourth for pump and ladder way. The shafts are timbered with 6x6 pitch pine setts. They are placed about five feet apart, and closely lagged until the pyritic zone is reached, when only the bare setts are carried. A handrail divides the ladder way from the sinking or hoistway.

Shaft sinking is usually done by machine drills worked by compressed air. This method, though more costly by from 30 to 40 per cent. than hand work, has the advantage of rapidity, and therefore the purely economic aspect loses somewhat of its importance. The speed of sinking averages probably not less from 80 to 100 feet per month for the first 300 feet, though a rate nearly double this has been attained, as for example in the "Catlin" shaft on the Simmer and Jack Estate where 142 feet was sunk in one month by hand labor.

Cost of Shaft Sinking.—This is made up of the following items,

which are taken from the evidence of Mr. P. M. Catlin before the Industrial Commision.

White labor	27.43	per cent.
Native do	33.00	"
Timber framing	15.35	"
Lubricants	0.56	"
Fuel	4.69	"
General stores	7.48	"
Maintenance	1.15	"
Office expenses	5.00	"
Explosives	5.12	"

The average cost of a shaft 18 feet by 5½ feet timbered in the manner described may be estimated as approximately £25 per foot.

The following figures are from the published balance sheets of various deep level companies:

Nourse Deep Limited.

By shaft sinking, 4055 feet £77,129 0 0

Glen Deep Limited.

By shaft sinking, 2022 feet 46,872 15 6

Langlaagte Deep Limited.

By shaft sinking, 2270 feet 74,922 2 10

Average per foot . . . . . £24 nearly.

The various percentage items calculated out on a £25 per foot basis will therefore figure out as follows:

White labor (including Mgrs' salary)	£. 6.86	per foot.
Native labor	8.25	"
Timber and farming	3.84	"
Lubricants	0.14	"
Fuel	1.17	"
General stores	1.87	"
Maintenance	0.29	"
Office expenses	1.25	"
Explosives	1.28	"

There is not, to my mind, any valid reason why incline shafts should be so universally adopted on the Witwatersrand. The advantages claimed are, that the reef is prospected during the sinking, and that a certain amount of ore is recovered, compensating in some measure for the cost of such. These advantages are,

however, only apparent, because in a majority of cases the shaft is set out at a certain inclination, and is continued at that, without reference to the reef, which usually pursues a more or less erratic course, and hence can seldom be kept in the shaft. It is usual, of course, to flatten the angle of an incline shaft at a given depth from the surface, to make allowance for the curvature which is common to almost all Rand mines. The practical disadvantages are:

1. Increased haulage length.

2. Greater wear and tear, and hence increased cost for maintenance.

3. Smaller haulage capacity on account of the restricted speed at which skips can be run on inclined planes.

I propose to speak more fully of this in reference to the location of deep level shafts.

Shaft Equipment.—This may be divided into:

1. Hoist.

2. Headgear.

3. Skip and skipway.

Hoist.—Almost every variety of hoist is to be found in use on the Witwatersrand. The pattern of steam winding gear mostly in favor on outcrop mines is a geared trunk-frame engine, upon the crank shaft of which are two pinions, each fitted with a clutch which gear into two pinions, each fitted with a clutch which gear into two spur wheels on the drum shafts, of which there is one to each drum. The ends of the drum shafts work in bearings fixed on a cast iron pedestal between the drums, which pedestal also forms a central bearing for the crank shaft. The drums have cast iron sides, and are so arranged that two different diameters of drum can be obtained, and hence the speed of winding may be varied, whilst maintaining a high piston speed. The drum flanges are from 12 to 15 inches deeper than the largest drum diameter. The valve gear is so arranged, that if necessary the engines can be reversed under steam. The crank discs are of large diameter and are fitted with band brakes, both being worked by one foot-lever off the engine man's platform. The drums are fitted with post or bar brakes, worked by hand-wheel and screw. The gearing is usually arranged for the engine to run up to a piston speed of 400 feet per minute, while the winding speed can be varied up to about 900 feet per minute. The sizes of these engines

mostly in use are from 14 inches by 30 inches, to 18 inches by 36 inches, working under a steam pressure of about 120 pounds.

Compound winding engines are in use on some of the mines, though they are not general.

On the Main incline shaft of the City and Suburban Company is a direct acting winding engine with 16-in. cylinder and 60-in. stroke. It is fitted with two independent drums 9 feet in diameter. The engine will wind safely at a rate of 3000 feet per minute. On some of the deep level mines the Whiting hoist is employed. I cannot do better than quote Mr. L. I. Seymour's description of this apparatus. In 1866 a system of winding engines was patented by Mr. S. B. Whiting, now the general manager of the Calumet and Hecla Copper Mines, which while allowing for almost unlimited extension obviates the necessity for large and extensive drums The improvement consists in the use of two grooved drums, one directly in line with the other, around both of which the rope from one compartment of a double shaft winds, and after making three round turns is led to the other compartment of the shaft. This arrangement has been almost universally adopted for cable tramway systems, but until lately has not been much used for winding purposes. The engines are preferably placed at the end of the shaft, instead of the side, one head sheave being directly over the other, especially when winding always from one level, as in coal mines, although by using a guide sheave this arrangement of drums may be placed in the ordinary position at the side of the shaft. To allow of winding from different levels, the rope after passing thrice around the drums, is led back around a sheave on a moving carriage, returning from thence to the head gear sheave. The track on which the carriage containing the take-up sheave works, requires to be half as long as the greatest distance between the upper and lowest levels to be hoisted from, since a movement of one foot in this carriage pays out or takes up two feet of slack rope. The track requires a strong anchorage at its extreme end, and if the changes to different levels be frequent, a steam winch must be connected to the carriage, for varying its position quickly. The drums are usually lined with wood blocks to save wear on the ropes, but iron rings are now frequently used on a system known as Walker's patent. The latter, while providing a harder bed for the rope, do not wear, they also allow for any creep of the rope on the drums without straining it.

Following are some particulars of a winding plant of this description as now used for sinking of the Calumet and Hecla mines:

Depth of shaft (present)	4426 feet.
Depth of shaft (ultimate intended)	5000 feet.
Diameter of rope (ultimate intended)	1¼ inches.
Number of turns of rope round the drums, . . .	3
Revolutions per minute	90
Speed of skip in shaft (feet per minute)	2000

The engines are directly connected to one drum, and by parallel rods, as in locomotives, to the forward drum which is inclined to the other by the width of one groove. They are a pair of tandem compounds, with Corliss valves, high-pressure cylinders of sixteen inches diameter, low-pressure cylinders of thirty-two inches diameter and all having a forty-eight inch stroke. The exhaust stream from the low-pressure cylinders goes to a Worthington jet condenser and air pump, maintaining about twenty-five inches vacuum. A foot break is used, reversing being done by a small steam reversing gear. The drum being small, the engine gets up to full speed in three or four revolutions, and steam is carried nearly to the end of the run. This engine has been used entirely for sinking the shaft, and works with extreme sensitiveness and regularity.

The Whiting hoists in use on these fields have not yet been worked at depths that other types are winding regularly from, and, therefore, no fair comparison can yet be made between them, hence I relegate such a comparison until further data is available.

Headgears.—The usual practice here is to make the headgear sufficiently large to include:

1. Grizzlies.
2. Sorting floors.
3. Rock breakers.
4. Waste and ore bins.

Some mines are equipped with the ordinary headgear which is common to colliery work in England. The Robinson Deep Level Company has erected iron headgears of a very elaborate design on its shafts, and it remains to be seen whether these will come into fashion and replace the enormously costly and massive wood structures which are now in vogue, some of which, as at the City and Suburban, cover an area of 115 × 20 feet × 65 feet high. There would appear to be more than ordinary inducement to substitute iron for wood in this country, because, firstly, of the total dearth

of indigenous timber of the size and quality required, and, secondly, of the extreme dryness of the climate in the winter months.

Air Compressors.—The variety of these in use on the Rand is endless. The deep level mines have favored the King-Riedler vertical triangular connecting-rod machine, probably for the reason that all these mines are in the hands of one or two financial groups, and, therefore, the same consulting engineer designs all the plans.

Some of the most recently erected mining plants comprise a compressed air equipment built by the E. P. Ellis Company, Wisconsin, U. S. A.

The Ingersoll-Sargeant is a very favorite machine and deservedly so. It is, however, so well known as to need no special mention. Of English makes the Yates-Thom and the Walker are probably most represented.

Electric Rock Drills.—Lately some excitement has been caused by the introduction of an electric drill called the Bladray, and which belongs to the class known as motor electric drills.

It consists essentially of the attachment to the bar or shaft of the drill of a cylindrical cam or hollow cylindrical piece, formed with a spiral cam or screw surface, in combination with an electrical motor, to which a corresponding cam or hollow cylindrical piece, formed with a spiral (or approximately spiral) cam, or screw surface, is affixed. The cam attached to the drill shaft is connected within a spiral, helical, or other suitable spring, to impart the requisite percussive motion to the drill immediately the cam fixed to the shaft reaches the limit of its throw, or maximum point of expansion.

The aim has been to reduce working parts to a minimum, and to subject those parts to the least possible pressure in working, in order to meet with a stoping machine requirements.

The requirements of a machine suitable for stoping we may state as :

1. Total weight not to exceed 130 lbs.
2. Few wearing parts.
3. Simplicity of wearing parts.
4. Maximum utilization of motive power.
5. Rapid and economical work.

All of these points, we believe, are included in the Bladray stoping drill. The drill weighs about 125 lbs. complete with cradle and feed gear, and is capable of delivering 900 blows a minute of

about 120 to 200 lbs., with an expenditure of about 1½ indicated horse power on the plant driving the dynamo. Being light it can be rigged in a well-ordered stope, to put in our holes without changing the position of the column. It can and has been safely run by a native.

The importance of a successful stoping drill to the mining community of South Africa cannot be over-estimated for the following reasons:

1. Fewer natives are required, involving amongst other things —(*a*) Fewer to house and feed; (*b*) Less cost for compound management; (*c*) Less capital for compounds; (*d*) Reduced medical and sanitary fees.

2. Machine work less costly.

3. Proportionately fewer natives to lower and raise.

Of the total native labor employed on the Rand 80 per cent. figures as underground workers, and about 70 per cent. is represented by hand drilling "boys." Each of these drilling or hammer boys is required to bore one three-feet hole each shift that he works. As a matter of fact in very hard stopes this average is not reached. In a Rand mine running 120 stamps, and working reefs of average width, about 850 hammer boys are required. Let us compare this number with the quantity necessary in a mine using a stoping drill. The basis of boring speed for the stoping drill, deduced from the results obtained by the experimental machine, has been taken as one inch per minute.

During a ten hour shift, the machine running continuously, it would be possible on this basis to drill an aggregate depth of 50 feet. Allowance has, however, to be made for rigging the drill, changing bits, etc., for which process 3½ hours will be allotted. The actual boring time in a ten-hour shift is therefore 6½ hours, in which time 32¼ feet, or eight holes of four feet each, would be bored. The aggregate boring of each machine per shift is therefore equal to the work that 11 Kaffirs would perform in the same time. Now, if one Kaffir handling a machine can do the work of 11, only 77 to 80 boys would be required in a mine employing these drills, against 850 for hand work.

This question more immediately affects the deep-level mines. It is patent that the cost to lower and raise 850 Kaffirs is a serious item. The time absorbed in the operation, in a shaft 1000 feet to 2000 feet in depth, assuming that each round trip only occupied

three minutes, could not be performed in less than one hour, using three-decked cages. In mines with deeper shafts, and greater stamping capacity, the cost and inconvenience of this operation will be proportionately more heavily felt.

Ore Storage Bins.—A feature of the Witwatersrand mining methods, is the construction at different levels of large storage bins. Room is made by blasting out a chamber in the hanging wall. The back of the chamber is cut down vertically to the shaft, and wooden bins, which are supported on heavy cross timbers resting on the sides of the shaft, and strutted with vertical uprights, are built in the space so made. The capacity of the bins is not infrequently from 200 to 300 tons. The object of these is to enable the trammers to tip the full trucks at once instead of waiting the arrival of the skip, thus avoiding any unnecessary waste of time. Their size also ensures steady work for the hoisting engine, and keeps the ore of the different levels separate.

To fill the skip, a door is opened in the floor of the bin immediately over the skip-way, the outpouring rock being easily controlled by the arrangement of the door. On reaching the tipping point on the headgear, an arrangement is provided which is designed to turn the skip into such a position that the ore or rock freely discharges from it to the grizzly below. The tilting of the skip is secured by using upon it a swinging bridle, and a different width of tread on the front and back wheels. Upon reaching the tilting arrangement the front wheels pass along the ordinary rail without hindrance, but the back wheels, because of their increased width, engage with a rail lying beyond the tread limit of the front wheels, and are carried into the tilting position by means of a little forward motion from the winding engine, the swinging bridle in the meantime remaining in the direct line of pull between the sheave pulley and load.

Levels.—The location of levels in a mine, that is the distance between level and level, varies as the inclination of the reef. If, for instance, a reef dips at an inclination of 20 degrees, the distance between the levels must be considerably less than those upon one which dips at 60 degrees, because at an angle of 20 degrees the inclination is too low to overcome the inertia of the mass of broken rock, and hence the entire bulk has to be handled for conveyance through the level to the shaft, and, therefore, as the limits are narrow within which broken rock can be quickly handled

by shovelling or kindred means, levels must be arranged to meet the special circumstances of the case. The distance between level and level will therefore vary in the manner stated. If, however, we assume as a basis our previously stated average dip of 35 degrees, then we may state what the rule in regard to levels is.

Probably 150 feet distances represents the most usual practice, the limits being 130 to 180 feet. Levels are driven about six feet in width by six to seven feet in height. Most of the work is performed by air drills. The rate of driving levels varies, of course, as the "tightness" of the rock. It is not uncommon to find a level driven from 150 to 180 feet per month, in the hard pyritic rock, though the average machine driving would not be much more than half of this, the discrepancy being due probably chiefly to the difference of air pressure applied to the drills by the different mines. I do not mean by this that there is any very great variation of pressure in the compressed air received on the different mines, but rather that there is a very great difference in the losses from leakage, etc., in the mains between the receiver and the drill. Some recent investigations upon this question have proved that this loss amounts in some instances to 46 per cent. of the total volume of air compressed by the machine. The rate of driving by hand-labor does not exceed from 30 to 35 feet a month.

The cost of machine driving, when all charges are proportioned against it, is probably not less than an average of £.5 per foot, and that of hand labor about £.3 per foot.

Crosscutting.—This forms a very large proportion of the dead work in a Witwatersrand mine, firstly, because two or more reefs are almost invariably worked, and, secondly, because of the reef displacement by dyke influence. Crosscutting in all working mines is done by machine work. The rate of advance is in general in the sandstone about the same as driving—when the crosscut is from north to south. If from south to north the progress is not so good. The reason for the increased footage accomplished when crosscutting from north to south, lies in the fact that the bedding planes of sandstone are, in such a case, dipping away from the face of the crosscut. When, therefore, a blasting occurs the tendency is to develop the said planes to the point of separation, and the weight of the rock itself assisting in the dislodgment, a very much greater burden of rock may be removed than in crosscutting in the opposite direction, where contrary conditions prevail. The cost of crosscutting may be reckoned to be the same as driving.

Ore Winning.—Various methods are adopted in stopping, determined principally by the reef's inclination. The first stages of blocking out ore are identical under each system, the later stages differing slightly in detail. Development work consists in the sinking of winzes, or putting in of raises, at intervals, the said winzes and raises connecting level with level for the dual purpose of providing ventilation in the drives and giving faces of attack within the ore body. The distances as between winze and winze, or raise and raise, vary within very wide limits. In some mines 150 feet may represent the interval, in others 500 feet or more may be the separating distance.

Assume that the reef dips at 35 degrees from the horizontal, the method would be as follows: Winzes would be placed at intervals, say of 300 feet; from each side of the winze at the lower points, stoping would first begin. The advancing stope would assume the form of an ellipse. In practical terms each advancing working face would form a breast stope, or a working almost equivalent to the long-wall method of coal winning, only in the case under notice the roof needs practically no support. A pillar is usually carried along the upper side of the level for protection and support, and through this, at short intervals, ore passes are put, in which are placed wooden boxes controlled by movable gates. In mining operations in the Transvaal generally the use of timber for roof support cannot be indulged in on account of its prohibitive price. The mazes of timber on the square sett system which are not uncommon in America and Australian metalliferous mines, are impossible in this timberless country. One is compelled to smile in looking at a stope probably 200 x 100 feet, and at a vertical depth of 400 to 500 feet, which is presumably supported on a dozen pieces of twisted bush sticks, none of which exceed 9 in. in diameter. At the depth indicated the static pressure is probably not less than 60 tons to the square foot.* The strength of the roof forma-

* This is probably a misprint. Thirteen cu. ft. of ordinary rock are usually taken to weigh one ton, so that at a depth of 500 ft. the static pressure would be $\frac{500}{13} = 38\frac{1}{2}$ tons per square foot. It may be pointed out, also, that in the case of an inclined vein only the normal component of the weight of the hanging wall is carried by either pillars or timbering. Thus, taking a dip of 30°, common in the mines of the Rand, the load at the above named depth, to be transmitted from hanging to foot-wall, through pillars and timbers, would be $38\frac{1}{2}$ tons $\times$ cosine $30^\circ = 33.3$ tons.

The roof of a large underground chamber, or stope, may be compared to a beam bridging across from one pillar to another. A part of the load may be carried by inter-

tion is well exemplified in instances of this kind, and doubtless in the present comparatively early stages of the mines, stopes of such demensions may be relied upon as self-supporting. The time is fast approaching, however, when these enormous open caves will have to be dealt with. In course of time the outcrop companies on a given reef will exhaust their upper workings to the divisional boundaries, and the result will be that the medium of support, adequate for the present unsupported areas, having been removed, these upper workings will cave. The proper precautions will of course be taken in the mine to protect the main hauling ways, so that as far as the mine is concerned, the caving cannot make any material difference. It is otherwise, however, with surface conditions. Many companies have enormous milling plants on the dip side of the reef outcrop, and the caving of the upper workings on the extensive scale which it seems probable may occur at some future date, will certainly affect the foundations of heavy machinery and buildings, even though these may be situated at some distance from the actual line of subsidence.

Stoping work is invariably done by hand labor; machines only being employed when the supply of natives is not equal to the demand. The practice is to allot to a white miner a given stope, wherein may be employed from 30 to 50 Kaffirs. The duty of the white man is to choose the sight and direction of the holes for the native drill boys; to superintend the operation of drilling and subsequently to charge and blast the holes. Each Kaffir is expected to bore one three-foot hole per shift; failing this performance in one shift he continues the work on the following day. An expert Kaffir can drill six inches an hour working with a 5-lb., hammer and ⅞-inch bore steel, hence the major portion of the drilling is finished at least two hours before the succeeding shift goes to work, during which interval the blasting takes place. It is usually estimated that each three-foot hole will break down one ton of rock, but I am inclined to the opinion that three-quarters of a ton is nearer the average and is probably, if anything, above the mark. There is no doubt that a three-foot hole located with

m diate timbers, but usually nearly the entire weight is supported by the pillars themselves, whether of ore or waste; and, as long as these stand intact the load upon the timbers may be but a small part of the actual weight of the overlying rock strata. In making these statements no account is taken of abnormal pressures which may be brought upon timbers by swelling or shifting ground.

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judgment, and bored truly in the intended direction, should break down a ton burden on the average Rand ore, and the average thickness of the reef, but with a Kaffir driller it is most difficult to have a true direction maintained. He will always endeaver to get the holes into such a direction, that the labor of drilling is minimized to the utmost, and the most careful attention on the part of the white miner only secures a small percentage of the holes in the direction he originally gave.

The costs of mining on the Witwatersrand are difficult to accurately assess, owing to a dissimilarity in the systems of bookkeeping on the various mines. For instance the Geldenhuis Estate mining costs for August are declared as 7 shillings per ton, whilst those of the Roodepoort United are 14 shillings. This enormous difference arises in the apportionment of the expenses. On the first named mine, for instance, the charge is purely for mining, other items, such as pumping, hauling, and maintenance, being separately charged. In the second instance the sum includes all the charges named, and also development.

For the purely mining work the Geldenhuis Estate figures represent probably the best Rand practice.

Pumping.—The quantity of water that has to be dealt with on the Witwatersrand mines is a mere trifle in comparison with that which has to be dealt with on many of the American and Australian goldfields, consequently a very light pumping equipment is all that is required. As the bulk of water is derived from comparatively shallow depths, the fashion is to use a Cornish pumping plant, with an independent pumping engine geared to a spur wheel, in which the pump crank is fixed. The usual size of the plunger is nine inches in diameter, and the working stroke five feet. Such a pump easily handles all the water in the mine. As auxiliary pumps it is usual to employ either the Riedler or three-throw electric pumps. The first named are worked by compressed air at a pressure of 65 to 70 lbs. One in use at the Geldenhuis Deep is placed at the bottom of a vertical shaft 600 feet in depth. The cylinders are compound, H. P. 10 in. L. P. 14 in.; with a 16-inch stroke. The plungers are 3⅝ inch and 5¼ inch, with 16-inch stroke. The water is raised at one lift, the engine running 150 revolutions per minute.

(To be concluded.)

SOME PROPERTIES OF A GASEOUS SUN.

By J. WOODBRIDGE DAVIS.

On page 162, Volume VIII., of *Wiedemann's Annalen*, occurs the following formula by A. Ritter:

$$\frac{u}{U} = 3(k - 1).$$

u is equivalent to the work performed by gravity in the contraction of a celestial spherical body from infinite dimensions to its present volume; U is the quantity of sensible heat necessarily possessed by the body, in order to maintain an equilibrium against gravity, on the supposition that the material of the globe is a perfect gas; k is the ratio of the two specific heats of a perfect gas, very nearly 1.4, which value will be used in this paper.

We shall take the liberty to substitute H for U, and W for u; then

$$H = \tfrac{5}{6} W, \quad \triangle H = \tfrac{5}{6} \triangle W. \qquad (1)$$

The value of W for the sun has often been computed; it differs with different assumptions of mass-distribution. A common estimate, found in Newcomb's *Popular Astronomy* and many other works is that W is equivalent to eighteen million times the heat now yearly radiated by the sun. In order to avoid the appearance of dealing with time, we shall say that W is equivalent to eighteen million year-units. It follows that the sensible heat of the sun, on the hypothesis that it is wholly gaseous, which hypothesis we shall retain through this paper, is equivalent to fifteen million year-units. This is much greater than the quantity of heat that further contraction can be expected to generate; hence, the future endurance of the sun as a source of radiant energy is due in greater measure to its past than to its future condensation. On the other hand, the heat already dispensed by the sun is only three million year-units.*

Let G be the total potential energy of gravity possessed by the sun, that is, the energy equivalent to its shrinkage to zero diameter.

* This is much at variance with the present doctrine of astronomers, according to which the sun has parted with all but an insignificant portion of the heat it has generated to the present time. In Clerke's *Popular History of Astronomy of the Nineteenth Century*, 1893, p. 378, occurs the statement that the fall of the sun's particles "must have engendered a vast thermal store, of which $\frac{4}{5}\frac{5}{4}$ths are computed to be already spent."

This is an infinite amount, but we shall have to deal only with its differentials. Correspondingly, let G_∞ be the value of G when the diameter of the sun is infinite. Then

$$W = G_\infty - G, \quad \triangle W = - \triangle G. \tag{2}$$

If I is a quantity of heat injected into the sun,

$$I = \triangle G + \triangle H; \tag{3}$$

or, by comparison with (1) and (2),

$$I = - \tfrac{1}{6} \triangle W = \tfrac{1}{6} \triangle G = - \tfrac{1}{5} \triangle H, \tag{4}$$

from which

$$\triangle G = 6I, \quad \triangle H = - 5I, \quad \triangle H = - \tfrac{5}{6} \triangle G. \tag{5}$$

When abstraction of heat is considered, I is negative.

We learn from (5) that the injection of any quantity of heat into the sun produces a six-fold effect in overcoming gravity, five times the equivalent of the injected heat coming to its aid from the heat of the sun itself; the abstraction of any quantity of heat causes a six-fold fall in the potential energy of gravity, one-sixth of which supplies the heat abstracted, and five-sixths of which is stored in the sun in the form of heat. Injection of heat cools the sun by five-fold the amount injected; and abstraction of heat causes the sun to become hotter by five times the quantity abstracted.*

From (5) $$H = H_1 - 5I, \tag{6}$$

where H_1 is the heat of the sun at present, and H is the heat after the injection of any quantity I. On page 364, Vol. XIII., *Wiedemann's Annalen*, 1881, Ritter proves that

$$\frac{H}{H_1} = \frac{R_1}{R}, \tag{7}$$

where R, R_1, are the values of the radius of the sun corresponding respectively to the values H, H_1.

From (6), (7),

$$R - R_1 = R_1 \left(\frac{H_1 - H}{H} \right) = \frac{5R_1 I}{H_1 - 5I}. \tag{8}$$

* The principle that a gaseous body under the impressment of its own gravitational force gains heat as a consequence of the abstraction of heat, was discovered by the late Mr. J. Homer Lane, member of the National Academy of Sciences, and is known as "Lane's Law."

To find the present yearly shrinkage, $2(R - R_1)$, of the sun's diameter, substitute for H_1 fifteen million year-units, and for I one year unit, negative; then

$$2(R - R_1) = -\tfrac{10}{15000000} R_1 = -1525 \text{ feet.} \qquad (9)$$

One-sixth of this, 254 feet, corresponds to the heat dispensed, and is the shrinkage contemplated in the Helmholtz theory; the remaining 1270 feet represents the heat yearly stored.

The effect of lessening the force of solar gravity is the same produced by the injection of heat. For instance, if the gravity force be diminished by the one-thousandth part of itself, the heat required to hold it in equilibrium is, by (1),

$$\tfrac{5}{6} \cdot \tfrac{999}{1000} W_1, \quad \text{or } \tfrac{999}{1000} H_1.$$

Hence the excess of the actual heat over the heat required in the new condition, is the $1 \div 999$th part, or approximately the one-thousandth part, of the actual heat. This heat produces a sixfold effect in overcoming gravity. I of formula (8) becomes one-thousandth part of H_1, and we find that the sun's diameter will increase by

$$2(R - R_1) = \tfrac{10}{1000} R_1 = 4330 \text{ miles.}$$

It follows that the tide-producing effect of the planets, although still insignificant, is very much greater than it would be if applied to a liquid sun, since in the gaseous body the planet's attraction liberates from bondage a quantity of heat that is far more effectual than the attraction itself; and the tidal effects between huge gaseous binaries greatly exceeds the effects computed from formulæ based upon the principles of liquid equilibrium.

These deductions, which the writer has made from Ritter's formulæ, relate, as do Ritter's formulæ, to a globe composed of only one kind of gas. The writer has, however, proved that they are also true of a globe composed of any number of gases of different molecular weights.

No.	DESCRIPTION.	SiO_2	Fe	Mn	S	Zn	Cu
1	Fume from the hood over breast of Cupel Furnace,						
2	" " " " " " " " " "						
3	" " " " " " " " " "						
4	Dust from Cupel Furnace Dust Chamber,						
5	Dust from Cupel and Concentrating Furnace Chamber,						
6	Cupel Furnace Bottom,						1.4
7	" " "						2.3
8	Dust near Cupel Furnace, in flue,						
9	Dust from Softening Furnace Flue,						
10	1st Skimmings of Softening Furnace,						
11	Fire Brick from side of Softening Furnace,						
12	Mixed Fume from Softening, Antimony and Refining Furnaces,						
13	White Fume from outside door of Softening Furnace,						
14	First or Copper Skims from Softening Furnace,	0.60	1.20	none	2.00	none	18.20
15	Liquated, first skims of Softening Furnace	2.00	2.80	none	3.60	none	26.80
16	" " " " "						26.20
17	Skimmings from Refining Furnace,	1.60	0.60		none	8.00	trace
18	" " " "	0.70	0.60	none	none	6.60	0.20
19	" " " "					8.00	
20	Retort fume on beams, running two weeks,						
21	" " " " " " "						
22	" " at base of stack,						
23	" ashes,	63.2	2.4				
24	" fume base of stack, large sample						
25	" " average of all of dust in flue,					12.20	
26	" fume, collected on top of Retort flue,						
27	" " " " " of iron columns						
28	Retort Ashes,	29.4	4.0			0.8	
29	" "	43.0	6.0				
30	Retort fume settled on plank near retorts					25.20	
31	Dust from the base of an 100-foot Refinery Stack,						
32	First Zinc skimmings from kettles,					13.20	4.40
33	Copper skimmings in liquating hard lead,	3.80	4.3		5.7	0.90	4.10
34	Antimonial or Hard Lead,						0.50
35	" " " "						0.60
36	" " " "						0.54
37	Litharge, average of 1 month's run,					2.10	4.10
38	First Zinc skimmings from kettles,					11.5	5.4
39	Unusually hard bullion, 30 to 34 hours for softening,						0.71
40	Fume from Antimony Furnace,						
41	" " Softening Furnace,						
42	" " Cupel, Concentrating and Silver Melting Furnaces					0.6	
43	" " Softening, refining and antimony furnaces,						
44	" " " " " " "						
45	" " Antimony, softening and concentrator furnaces,						
46	" " Softening and concentrator furnaces,						
47	" " " " " "						
48	" " " " " "						

PRODUCTS.

Sb	Al_2O_3	FIRE ASSAY. Ag oz.	Pb %	Au oz.	REMARKS.	
		134.3	41.8	0.32	Balbach Refinery, Newark, N. J.—Walker	
		135.2	41.8	0.32	" " " "	
		135.2	38.5	0.32	" " " "	
		71.5	16.6	trace	Globe Refinery	
		106.6	27.6	0.40	Light gray color, putty-like when moistened	Globe
		702.0	45.0	10.4	Sample of the entire bottom	Globe
		547.0	37 6	6.0	" " " "	Globe
		67.0	57.0	0.32		Globe
		30.0	33.8	0.16	Sample taken 10 feet from furnace	Globe
		147.4	96.5	4.10	Germania Refinery, Salt Lake, Utah	
		126.0	35.5	trace	Sample taken during repairs upon furnace	Globe
4.28		5.0	20.8	trace	Globe	
32.73		7.0	20 6	0.05	Sample taken whilst using air to hasten softening	Globe
		180.0	53.0	12.00		Globe
1.18		75.0	50.0	0.30		Globe
					Month's average	Globe
4.02		1.0	78.0	min. tr.		Globe
not deter.		0.7	71.0	none		Globe
		0.7	78.0	none		Globe
		21.0				Globe
		13.0	1.20	trace	Product consists mainly of ZnO	Globe
		10.8	trace	0.16	" " " " and ashes of coke	Globe
					Very liable to contain gold, silver and lead.—Colorado Coke	Globe
		29.70	0.6	0.32	Presence of gold particularly noticeable	Globe
		16.80	0.5	0.20		Globe
		38.50	trace	trace		Globe
		44.00	trace	trace	Sample close to retorts	Globe
	12.30	1.00	trace	trace	Using Connersville Coke	Globe
	31.20	1.40	trace	trace	Gunnison, Colorado, Coke	Globe
		44.0	1.30	1.12	Rather large sample	Globe
		71.20	38 70	0.08	General mixture of smoke from all kinds of refining furnaces	Globe
		2904.	67.0	3.00	Park's Process—zinc skimmings	Globe
17.0		4.8	31.2	0.14	Antimonial Lead, copper skims	Globe
25.97		2.4		0.05	Analysis by Von Shultz and Low, Denver, Colorado	Rand
25.95					" " Professor W. B. Potter, St. Louis, Mo	Rand
26.86		1.92	71.52	0.021	" " Globe Laboratory—6th Run	Globe
						Globe
		2217.	73.5	63.4		Globe
3.27		240.	95.35	2.00	Analysis by Professor W. B. Potter, St. Louis, Mo	Globe
2.88		7.2	38.3	trace	Collected with textile fabric	Globe
10.45		32.5	19.20	trace	" " " "	Globe
trace		85.9	72.50	0.10	" " " "	Globe
3.56		7.0	20.5	trace	" " " "	Globe
		288.0	28.0	0.36	" " " " mostly softening furnace fume	Globe
		149.0	62.0	trace	" " " "	Globe
		115.0	52.0	trace	" " " "	Globe
		86.0	72.0	trace	" " " "	Globe
		87.0	72.0	trace	" " " "	Globe

REFINERY PRODUCTS.

By MALVERN WELLS ILES.

In the table marked refinery products will be found quite a number of fire assays and analyses upon various metallurgical products resulting by the Parke's Process from the treatment of lead bullion, containing gold and silver.

In the study of any metallurgical operation, the student should have a very intimate acquaintance with the composition of the resulting products; but, unfortunately, this statistical knowledge is very often sadly lacking in text-books.

So far as lead metallurgy is concerned, we had but little literature upon the assays and analyses of the great multitude of highly interesting products, until this want was supplied in a most thorough and masterful manner by Professor Hofman. I trust the slight contribution I now make will prove of interest and value to the readers of the QUARTERLY.

I will add that the lead determinations were made both by fire assay and also gravimetrically by the highly accurate method developed by my able assistant, Mr. H. H. Alexander; and that the lead determinations reported in the table were performed by the Alexander method.

WILLIAM ALLEN SMITH.

The Alumni Council of Columbia University, convened in Special Session after the death of Mr. William Allen Smith, late Secretary of the Council, desires to enter upon its records an expression of esteem and affection for him and of regret because of his sudden death.

Graduated as an Engineer of Mines in 1868 from the School of Mines of Columbia University, then but recently established, he had the distinction of being among the first, as he has always been one of the most respected of its alumni.

In 1895 he was chosen President of the Association of the Alumni for the ensuing year. So acceptable to the Association was his presidency that he was successively re-elected until at his

own express desire in 1898 he was relieved of the responsibility. He brought to this work the same devoted interest and self-sacrifice that have characterized all his public relations.

Professionally he paid special attention to the Departments of Metallurgy having to do with the production and manufacture of iron, and was the Secretary of the Harvey Steele Company. He carried successfully the burden of the technical management of important litigations relating to patents upon the process which has had an all-important bearing upon the development of armor plate in America.

When it was decided to create the Alumni Council, Mr. Smith was an early appointee of the School of Mines Alumni Association and served actively in the work of legislation as Secretary of its Committee on Organization, and was thereafter chosen the Secretary of the Council. So faithfully and conscientiously did he attend to the exacting details of this work and so satisfactory was his discharge of the duties of his difficult office, that his colleagues re-elected him year after year; and it adds to the sense of personal loss that the Council is to be deprived of his devoted services. He was the speaker for his Association at the first formal reunion of the associated alumni at the Commencement of 1898, and was also the speaker at many informal gatherings for which this body had provided.

But the members of the Council feel most strongly the sense of personal bereavement in the loss of their friend and the man. He had a rare combination of strength with warmth of affection; and his genial personality, his unfailing cheerfulness, his sound judgment, his tact, his high Christian character and his unselfishness will live in memories which his colleagues will long cherish.

When personal affection speaks so strongly, it is difficult to make a formal expression of the desire that those who have been most intimately affected by Mr. Smith's death should know that they are not alone in their grief, and that they have the heartfelt sympathy of his friends and former associates.

The Chairman of the Council is therefore requested to inform the family of Mr. Smith of the action of the Council by such letter as may be appropriate, and to transmit to them a copy of this minute.

Resolved, That copies of this minute be published in the *University Quarterly* and in the *Columbia Spectator*, and the SCHOOL OF MINES QUARTERLY.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

BY ELWYN WALLER.

Filtering device. Sargent and Faust (*J. Am. Chem. Soc.*, XXI.). For some precipitates as MnO_2 Phospho-molybdate, etc., a filter made of sand placed in a carbon filtering tube, and covered with a thin layer of asbestos, has been found very satisfactory. A small plug of glass wool is used below to retain the sand in place, and the filter should be washed three or four times with HNO_3 before using.

Indicators. Lakmoid, Phenacetolin and Erythrosine (alkalimetry, etc.), Ellms (*J. Am. Chem. Soc.*, XXI., 359). The technique of the process consists in warming 100 cc. of the solution to be tested over the water bath until gas bubbles begin to rise, and then removing from the heat and titrating. Hehner's plan (using fiftieth normal solutions) was tried. A certain allowance for the amount of indicator used must be made in very close work; 0.5 cc. of the solution of each indicator was used. The three indicators proved to be, to all intents, equally satisfactory in tests on carbonates of Na, Ca and Mg.

New Alkalimetric indicator. Riegler (*Bull. Soc. des Sci. Bucharest per Chem. News*, LXXIX., 192). A solution of guiacol in alkali mixed with a solution of diazo-para-nitr-aniline gives a diazo body $C_6H_4(NO_2)-N=N-C_6H_3O.CH_3.OH$. This substance is brown, insoluble in water, but soluble in alcohol. With alkalies it gives a red, with acids a greenish yellow. Its sensitiveness is greater than that of phenol phthalein.

Determining Potash. Bell (*Chem. News*, LXXIX., 135). With fertilizers, boil 5 or 10 gms. of the sample with 150 cc. water; For soils extract with dilute HCl; For vegetable substances moisten the organic matter with H_2SO_4, ignite, and then extract with dilute HCl. In any case after extracting, add NH_4OH until the solution is slightly alkaline, then, *without filtering*, add excess of $BaCO_3$ (about double the weight of the material taken) and boil 30 minutes. Then filter and wash making the bulk up to 500 cc. Take 50 or 100 cc. of this solution, add a little $(NH_4)_2C_2O_4$ evaporate to dryness, ignite gently, treat with hot water filter add HCl and $PtCl_4$ and evaporate down, conducting the remainder of the operation in the usual manner.

Separation of Rubidium and Cæsium. Lemoine (*Bull. Ass'n Belge*, XII., 344). The usual method consists in treating the mixed carbonates with absolute alcohol, which dissolves Cs_2CO_3 leaving Rb_2CO_3 which is practically insoluble. To convert from chlorides to carbonates, the author finds the most convenient method is to digest with excess of Ag_2CO_3 for some time on the water bath.

Determining alkaline earths in presence of one another without previous separation. Knobloch (*Fres. zts. Anal. Chem.*, XXXVII., 734). After qualitative tests to determine whether one, two, or all three (Ca,Sr, Ba) are present, the earths are precipitated as carbonates, and weighed as such. The filter paper being ignited separately and the whole treated

with $(NH_4)_2CO_3$ and heated carefully at a temperature insufficient to causticize (below red heat). Then about 8 gms. of strictly C.P. Borax is heated in a platinum crucible at the full heat of a Bunsen burner for two hours, cooled and weighed. To this is then added the alkaline earth carbonates, and heat is applied carefully at first until the effervescence of CO_2 has practically ceased, when a strong heat is applied for an hour, the crucible being surrounded by a clay chimney. After cooling the increase in weight is due to the oxides. Knowing the weight as carbonates and as oxides, the respective amounts can be calculated easily when but two are present. In case all three are present, the Ba is separated out by K_2CrO_4 in a solution slightly acid with acetic.

Iron Separation. Brearley (*Ch. News*, LXXIX., 193). The separation of Fe by basic acetate (from Ni for instance) is stated to be most satisfactorily effected by bringing the nearly neutralized solution to boiling, and then adding a limited quantity of $NH_4C_2H_3O_2$. An excess of acetate gives rise to formation of $Ni(C_2H_3O_2)_2$ which also partially decomposes by the boiling, defeating the object aimed at.

Errors in Electrolytic determination of Iron. Avery and Dales (*Ber*, XXXII., 64). Classen's (oxalate method,) results very exact. Deposited metal contains 0.15 to 0.5 per cent. C. A corresponding amount of Fe remains undeposited.

Smith's (citric acid and $Na_3C_6H_5O_7$). Some Fe remains in solution as above, C in the deposit 1.2 to 5 per cent. of the whole, hence results are always high.

Moore's (ammon. metaphosphate) results slightly high, all Fe not deposited. Deposit contains a little C, also P.

Manganese as Phosphate. Gooch and Austin (*Zts. anorg. Chem.* XVIII., 339). A considerable excess of NH_4Cl—200 mol NH_4Cl to 1 of $MnNH_4PO_4$ is indispensable to effect complete conversion of $Mn_3P_2O_8$ into the ammonia compound, which is not appreciably soluble if a decided excess of alkaline phosphate is present.

Electrolytic for Manganese. Koeppel (*Zts. f Anorg. Chem.*, XVI., 268). Dissolve in 150cc, add acetone 1.5 to 10 gms. Get at temperature of 50 to 55°C and electrolyze with a current of 4 volts or over, and 0.7 to 1.2 amp. Add water gradually to replace what is lost by evaporation. In 2 to 5½ hours, according to the proportion of acetone present, the operation is concluded; wash the electrode without interrupting the current, dry at 150° to 180°C and weigh.

A method sufficiently accurate for commercial purposes (?) consists in adding a sulphate solution to a boiling solution of $Na_4P_2O_7$, adding 3 or 4 drops of H_3PO_4, and electrolyzing at 30° to 40°C., with a current of 1.8 to 2.5 amperes for 8 or 9 hours.

Zinc Estimation. Langmuir (*J. Am. Chem. Soc.*, XXI., 125). It is here proposed to dissolve the ZnS obtained (as in the usual course of separation) in HNo_3 to boil down in a casserole to small bulk, and then to transfer to Pt. dish finally drying and igniting to ZnO.

Examination for Nickel. Edwards (*Eng. and Min. J.*, May 28, 1898). Dissolving in HCl and KCy titration.

Prepare solution A 11 gms. commercial KCy (98 per cent.), and 0.5 gm. $AgNO_3$ in 1 litre of water.

Solution B, 50 gms. $H_3C_6H_5O_7$ 38 gms. (approx.) Na_2CO_3, 7.5 gms. KI in 500 cc.—35 gms. of the Na_2CO_3 are first added, then so much of

the remainder, little by little until the solution is neutral or slightly alkaline, after that add the KI.

Treat 2.5 gms. of ore in a 250 cc. flask with 20 cc. HCl, until decomposed—make up to the mark and shake well, filter off 50 cc. to which add 10 cc. of sol. B, then dilute NH_4OH until there is a slight excess giving the blue solution. Then titrate with solution A added slowly with stirring. A white cloudiness appears at first, but disappears when the end is reached. Standardize by using a solution containing a known amount of pure Ni.

Thirty minutes are required for the process. Results are usually a little high. Ores containing over 25 per cent. Fe or Mn or over 1 per cent. Co, cannot be accurately tested by this method.

Analysis of Ferro Tungsten. McKenna (*Proc. Eng. Soc. Wn. Pa.*, XIV., 171). Fuse 0.5 gm. of the finely powdered sample with 3 gms. Na_2O_2, raising the heat to a full red for about one minute, the crucible being held in the tongs during the operation and kept in motion to prevent the sample from settling. A *copper* crucible is preferred, as having advantages over the nickel crucible for this kind of work. Cool, extract with water, add a little alcohol to render Mn insoluble, and filter. Evaporate the filtrate to dryness twice with HCl, take up with dilute HCl, boil and filter, wash the residue with dilute HNO_3 (1:10). Dissolve the insoluble matter from the fussion in hot dilute HNO_3 and evaporate to dryness, take up with HCl and filter through the same filter containing $SiO_2 + NO_3$ washing with dilute HNO_3 as before. Dry and weigh $WO_3 + SiO_2$ then expel SiO_2 by use of HF and H_2SO_4 and weigh.

Tungsten in steel. Auchy (*J. Am. Chem. Soc.*, XXI., 239). In the method given a final separation and determination of the Fe contaminating the WO_3 is described. Attention is called to the fact, that within certain limits of proportion of W, the amount of Fe_2O_3 in the WO_3 weighed is very nearly constant, *e. g.*, in steels containing under 1 per cent. W, the Fe_2O_3 contamination is between 0.02 and 0.03 per cent.; (reckoned as W) when 1 to 2 per cent. W is present the contamination is 0 03 to 0.04 per cent. (reckoned as W). The author recommends solution of 4 gms. of the steel in dilute HNO_3, evaporation to first appearance of a scum on the surface of the liquid; addition of 30 to 40cc. conc. Hce; evaporation to dryness, and heating on the hot plate; re-solution in a 40 cc. conc. HCl; evaporation to first appearance of scum; taking up with 5 cc. conc. HCl diluted to 20 cc. with water, and heating; addition of 25 to 30 cc. hot water; and filtration, etc. With ferro tungstens gave good results when aqua regia instead of HNO_3 was used as a solvent. The ferric contamination appeared to be variable in ferro tungstens containing up to 35.+per cent. W.

Tungsten Estimations. Brearley (*Chem. News*, LXXIX., 64). The estimation as $PbWO_4$ has been made the subject of inquiry. Boiling $PbWO_4$ with an excess of conc HCl dissolves it to a clear solution. By continued boiling opalescence begins, and further boiling throws down WO_3, if the solution is diluted four or five times and boiled for a short time. The precipitate is soluble in conc. HCl, and if the dilution has been effected before the first precipitate turns yellow, it will not stick to the sides of the beaker, HNO_3 precipitates WO_3 more readily, but portions of the precipitate adhere to the glass. The precipitate must be washed with dilute HCl. To obtain standard solutions for these experiments,

difficulty was experienced in obtaining pure WO_3 since the "Wolframsaure puriss," was found to contain Mo. $PbNO_4$ precipitated from acid solutions (even acetic) was found to contain an excess of WO_3. Certain neutral salts were also found to affect its composition.

The plan found to be applicable in order to obtain actual $PbWO_4$ was to add to the alkaline tungstate 2 or 3 gms. of NH_4NO_3, a faint excess of HNO_3 (boil a few minutes) a small excess of NH_4OH, and then an excess of $Pb(C_2H_3O_2)_2$. This gives a little basic Pb salt in the precipitate, which is dissolved by brisk boiling for a few minutes. The true $PbWO_4$ becomes denser by boiling, and may be filtered off, ignited and weighed.

Separation of Zirconium from Iron. Matthews (*J. Am. Chem. Soc.*, XX., 846). It has been found that if the metals are obtained in the form of chlorides, and the solution evaporated to dryness, treatment with ether through which dry HCl gas is passed, will dissolve the Fe_2Cl_6, leaving insoluble the $ZrCl_4$ or $ZrOCl_2$, and the satisfactory separation may be thus effected. The method was also successfully applied in separation of Fe from Th, Ce, Ti, La, Pd and Nd.

Available Molybdenum in Molybdenite. Bornträger (*Zts. Anal. Chem.*, XXVII., 438). Digest 1 gm. in an Erlenmeyer for 2 hours with 25 cc. conc. HNO_3, until all Mo has been converted to MoO_3. Then add NH_4OH to dissolve the acid and filter. Digest the residue again and treat in the same manner. Neutralize the combined solutions with HNO_3, and evaporate to dryness. Treatment with 50 per cent. alcohol will then take out the NH_4NO_3, leaving MoO_3, which may be weighed directly, or dissolved up in standard NH_4OH solution and titrated back with standard acid.

Estimation of Metals when precipitated as sulphides. Weber (*Fres. Zts. f Anal. Chem.*, XXXVIII., 48). By boiling certain of the sulphides of the heavy metals with $Fe_2(SO_4)_3$, and titrating with standard $K_2Mn_2O_8$, many of these metals may be accurately estimated.

The washed sulphide is rinsed into a beaker, pulverized $Fe_2(SO_4)_3$ in excess added, and the mixture boiled for 15 minutes. Conc. H_2SO_4 is then added (about 15 cc.) in the case of Sb_2S_3 until the precipitate present is dissolved. The solution is transferred to a 200 cc. flask, and after cooling, filled to the mark, when 100 cc. are filtered off and titrated with standard $K_2Mn_2O_8$. The best results are obtained with Sb_2S_3 when not over 0.2 to 0.3 gm. of the sulphide are treated. With PbS when about 0.3 gm. Pb are present results are good. The same is the case with Bi. Hg or As, cannot be estimated in this manner.

Precipitation of Platinum. Atterberg (*Chem. Ztg.*, XXII., 538). Thioacetic acid, Hg and Mg may be used. The first gives a voluminous precipitate and is good when very small amounts of Pt are present.

For separating Pt from a filtrate when Na is to be determined Hg is the best. The solution should be concentrated in a rather deep porcelain dish, Hg added, and the whole well stirred *while warm* until the reaction is finished. $HgCl_2$ forms which can be easily volatilized. When the Pt is to be weighed, Mg ribbon is the best. The solution should be acidified with HCl. The precipitation is more rapid when the solution is heated, though it will take place in the cold. A portion of the metal will remain suspended in finely divided condition for some time, so that it should not be filtered unless absolutely bright

Gold and Platinum-volumetric. Peterson (*Zts. Anorg. Chem.*, XIX., 59). Treatment of a solution of the salts of either metal with KI solution sets free I quantitatively which may be titrated with standard $Na_2S_2O_3$ *without starch.* $PtCl_4 + 4\,KI = PtI_2 + I_2 + 4\,KCl$ and $AuCl_3 + 3KI = AuI + I^2 + 2KCl$.

$AuI + Na_2S_2O_3 = NaI + AuNaS_2O_3$.

Lead in Ores. Moldenhauer (*Chem. Ztg.*, 1898, 256). Pulverize finely. Boil 2 gms. with strong HCl until the attack is complete. If much Sb is present, evaporate three or four times with HCl to eliminate it. Then add HNO_3, drop by drop, and evaporate to dryness. Take up with strong HCl, add 80 to 100 cc. of water, boil and filter hot, washing the residue with hot dilute HCl. Neutralize the filtrate with NH_4OH added in sufficient amount just *not* to produce a precipitate, and pass H_2S while warm. Filter, washing with dilute $(NH_4)_2S$. Partially dry the precipitate by compressing between two sheets of filter paper, place in a large porcelain crucible (covered with a watch glass), add HNO_3 and oxidize by heating, finally calcining over a low flame. When cool, add conc. H_2SO_4, heat to a boil to bring the PbO into solution, cool, pour into water, and separate and weigh the $PbSO_4$ in the ordinary manner.

Bismuth Estimation. Vanino and Treubert (*Ber.*, XXXI., 1303). By mixing a slightly acid solution of Bi salt with formaldehyde and adding a large excess of 10 per cent. solution of NaOH, Bi is separated in metallic form. After heating on the water bath with stirring until the supernatant solution is clear, more formaldehyde and NaOH solution is added, and the heating prolonged. Wash by decantation with boiling water, knead the precipitated metal into a mass with the stirring rod, and finally filter through a weighed (Gooch) filter, wash with absolute alcohol, dry and weigh.

Volumetric for Bismuth. Reichard (*Fres. zts. Anal. Chem.*, XXXVIII., 100). Depends upon reduction of Bi_2O_5 to Bi_2O_3 by As_2O_3 in alkaline solution, and estimation of excess of As_2O_3 by titration with standard $K_2Mn_2O_8$.

A weighed amount of the substance containing Bi is treated as may be necessary to separate that element. The Bi is then brought into acid solution, and an excess of alkali added. Cl water is then added or Cl gas passed in, and the precipitate boiled until its color has changed to dark red Bi_2O_5.

After washing off the excess of Cl by repeated decantations, a measured excess of standard alkaline solution of As_2O_3 is added, and the material is boiled until entirely converted to white $Bi_2(OH)_3$. H_2SO_4 is then added to strong acid reaction, and the solution is filtered hot. It is then titrated with standard $K_2Mn_2O_8$.

It is advisable that one should work with rather small quantities of Bi, since with large amounts the time required for reduction is very long. This can be somewhat shortened by the use of concentrated solutions.

Delicate reagent for Copper. Bach (*C. Rend.* CXXVIII., 363). The reagent is formaldoxine hydrochloride, made by mixing a 20 per cent. formaldehyde solution in equi molecular proportion with hydroxylamine hydrochloride. The reagent may be preserved indefinitely. 0.5 cc. of this reagent added to 15 cc. of a solution containing minute amounts of Cu give an intense violet color. One per million of Cu may be thus

detected. If the Cu solution is too strong the color is deep green, and the violet tint is only seen on dilution. The solution should not contain metals of the iron group.

Colorimetric estimation of Copper. Lucas (*Bull. Soc. Chem.*, XIX., No. 18). The method differs but little from that of Carnelly (*C. N.*, XXVII., 308) the depth of coloration obtained by use of ferrocyanide, especially when in presence of NH_4NO_3.

Volumetric for Copper. Meade (*J. Am. Chem. Soc.*, XX., 610). Bring the Cu into solution as sulphate. Neutralize the most of the free acid with NH_4OH, warm, add H_2SO_3 or alkaline bisulphite to reduce, and precipitate Cu. by NH_4CNS. Filter through asbestos and wash well; then heat with solution of NaOH (or KOH) of about semi-normal strength. Cu_2O remains, which is filtered on asbestos, washed, and the Cu determined by its reducing power $Fe_2(SO_4)_3$ or Fe_2Cl_6 in H_2SO_4 solution, by digesting them together, and then titrating with standard $K_2Mn_2O_8$. Fe standard $\times$ 1.125 = Cu standard.

Adsorption test for Cadmium in presence of Copper. Trey (*Fres. Zts. Anal. Chem.*, XXXVII., 743). The solution received the addition of ammonia until it showed the blue coloration (presumably to resolution of the light bluish precipitate). A drop of this solution was then allowed to wet the center of a disc of filter paper. In extending by capillary action, Cd salt will extend outside of the part wetted by the Cu (adsorption) and testing with $(NH_4)_2S$ shows a yellow ring surrounding the brown spot due to CuS. The author devised a simple apparatus for making these tests consisting of a piece of ordinary tubing bent in U form with one end expanded to funnel shape, the other end drawn down to a fine jet, the whole set in a large flat cork, with a small wire frame to support the filter paper which is to be laid over the jet.

Volumetric for Mercury. Reichard (*Fres. zts. Anal. Chem.*, XXXVII., 749). As_2O_3 in alkaline solution when boiled with mercuric salt reduces it to metallic form. Hence, if an unknown amount of mercuric salt is boiled with an excess of standard As_2O_3 solution (alkaline) the amount of unoxidized As_2O_3 may be determined by titration with $K_2Mn_2O_8$, and the measure of the Hg in terms of O may be found.

Hydrofluoric Acid. Zellner (*Monatsheft f. Chem.*, XVIII., 749). This acid may be titrated direct by over neutralizing with an excess of normal alkali, boiling for a short time and then titrating back, using phenol phthalein indicator. Titrations in the cold give concordant but low results.

Polysulphides in Ammonium Sulphide. Chandelon (*Bull. Assn. Belge*, XII., 277). A strip of bright Cu in $(NH_4)_2S$ solution free from polysulphides will remain bright for several days. Polysulphides causes blackening in a few hours.

Tetra-thionates in Thio-sulphate. Chandelon (ib). Metallic Cu is blackened (by formation of CuS) immediately by tetrathionate ($Na_2S_4O_6$) but not by thio-sulphate ($Na_2S_2O_3$).

Determining Sulphurous and Hyposulphurous Acid. Autenrieth and Windaus (*Fres. Zts. Anal. Chem.*, XXXVII., 290). Sulphide may be separated by addition of $ZnCl_2$. In the filtrate, the addition of $Sr(NO_3)_2$ or $SrCl_2$ will precipitate $SrSO_3$. By titration of the original solution with tenth normal I solution, then in another portion titrating after the Zn treatment, and finally in another portion after both Zn and Sr

precipitation, the necessary data are obtained for estimation of the three forms of S compounds. Or the $SrSO_3$ precipitate may be dissolved in dilute HCl and titrated with N/10 I.

Incidentally the authors determined the solubilities of the alkaline earth sulphites and hyposulphites in water; found to be:

	Sulphite	Hyposulphite
Calcium	1 in 800	1 in 2
Strontium	" 30000	" 3.7
Barium	" 46000	" 480.

Determination of Sulphuric acid in presence of Iron. Jannasch and Richards have asserted (*J. Pr. Chem.*, XXXIX., 321) that the cause for the interference of Fe with the $BaSO_4$ precipitation, is that some basic ferric sulphate always accompanies the precipitate, which by ignition loses SO_3. Kuster and Thiel (*Zts. f. Anorg. Chem.*, XIX., 97) have made some experiments, the results of which tend to show that the error is always proportionate to the amount of ferric salt present. Precipitation of the Fe by ammonia they find causes error since some basic sulphate separates with the hydrate. By adding ammonia, and *not filtering off*, then the $BaCl_2$ and afterward acidifying with HCl, correct results, with white $BaSO_4$ were obtained. Also, it was found that by addition of $(NH_4)_2C_4H_4O_6$ solution before adding $BaCl_2$, complex Fe ions were formed, which did not permit the formation of basic ferric sulphate in the precipitate.

Lunge (*ib.*, XIX., 454) criticises their work, asserting that the separation of Fe by ammonia before precipitating with $BaCl_2$ if properly performed causes no error.

Heidenreich (*ib.*, XX., 233), accepting the assertion of Jannasch and Richards, proposes to convert the Fe to ferrous form, by addition of metallic Zu before adding $BaCl_2$. His test analyses show accurate results.

Superphosphate analyses Vignon (*Bull. Soc. Chem.*, XIX., No. 20). The citrate soluble P_2O_5 may be estimated directly by Mg mixture in the citrate solution after having extracted the water soluble P_2O_5 by treatment with water, or else by taking two portions of the sample, in one of which water soluble P_2O_5 is determined, and in the other the *combined* water soluble and citrate soluble P_2O_5. The two plans do not give concordant results when the citrate soluble P_2O_5 is low, the direct determination giving the lower result. The indirect method is advised.

Silica in Portland Cement. Shimer (*J. Am. Chem. Soc.*, XXI., 239). Treatment with HCl and evaporation to dryness, etc., in some cases, has given results for SiO_2 differing by 1 to 2.5 per cent. from the fusion method. Such differences are indicative of insufficient burning of the cement. The point serves as a warning, and at the same time as an indication of the degree of burning to which the cement has been subjected.

Boric Acid. Gooch and Jones (*Am. Jour. Sci.*, VII., 1899). The separation of B_2O_3 by distilling with HNO_3 and methyl alcohol, and catching the distillate in a receiver containing CaO which is subsequently ignited, was worked out by Gooch long since (*Am. Chem. Jour.*, IX., 23). Some further details are given with the use of acetic acid instead of HNO_3, confirming the plan previously given, and showing experimentally the efficiency of CaO as used in the process, a point comparatively recently questioned by Thaddeeff, Na_2WO_4 with a slight excess of WO_3 was found to be an excellent retainer for B_2O_3. Blyth, *Proc. Lond.*

Chem. Soc., Feb. 16th, 1899, describes methods based 1 on the polariscopic rotation, and 2 on the electrical resistance of boric acid and solutions.

Carbon in Iron and Steel. Wdowiszewski (*Fres. zts. Anal. Chem.*, XXXVII., 742). To dissolve out Fe by treatment with $(NH_4)_2CuCl_4$, the iron or steel is weighed out in an Erlenmeyer flask, provided with ground stopper, the necessary amount of water and copper salt added, the stopper clamped in firmly and the flask shaken in a shaking machine for five to eight minutes, when both Fe and Cu will have been dissolved.

Kjeldahl Method. Atterberg (*Chem. Ztg.*, XXII., 505). Kellners method (a modification of Gunnings) was found to be the best, K_2SO_4 is not added until the H_2SO_4 has dissolved the material whereby frothing is avoided. The best mixture was found to be 20 cc. H_2SO_4 15 to 18 gms. K_2SO_4 and a small drop of Hg. When frothing is not to be expected the K_2SO_4 may be added at once. Decolorization takes place in about 30 minutes, but the mixture should be boiled for about 15 minutes longer, before cooling, dilution, etc.

Direct estimation of Nitrogen in Coal Gas. Kent Smith (*J. S.*, CIXVIII., 213). The essential feature of this process is the slow passage of the gas through a tube filled with incandescent CuO, which affords $H_2O_1SO_3CO_2$ and N. By passage through alkaline solution only N remains in the gaseous form, and may be measured.

Determination of Nitrite and Hyponitric. Grutzner (*Arch. d Pharm.*, CCXXXV., 241). In acid solution the lower oxide of nitrogen will quickly reduce $HClO_3$, thus: $3HNO_2 + HClO_3 = 3HNO_3 + HCl$. The HCl can be determined by means of $AgNO_3$. The process is managed in this manner. Material to be analyzed containing 0.1 to 0.2 gm. of nitrite is dissolved in about 500 cc. of water, which solution is placed in a stoppered flask of about 1 litre capacity, with about 0.5 gm. $KClO_3$ free from chloride, and a measured amount of N/10 $AgNO_3$ solution (25 or 50 cc.). The mixture is then strongly acidified with HNO_3 or H_2SO_4. The stopper is then inserted and the mixture allowed to stand some time with occasional shaking. The excess of Ag salt remaining in solution may then be titrated back with N/10 NaCl solution or by Volhard's method with standard NH_4CNS solution. The calculation is made on the basis of the above equation. To determine N_2O_4 in fuming HNO_3, the process is essentially similar. The acid (about 5 cc.) is allowed to flow in a thin stream into a comparatively large bulk of water (about 750 cc.), which is kept in motion during the addition. The nose of the pipette should be close to the surface of the water. Then add 1 gm. $KClO_3$ and 50 cc. standard $AgNO_3$ solution as before, stopper; let stand 10 or 15 minutes, add iron alum solution and titrate with standard NH_4CNS.

Determining Nitric Acid. Ackermann (*Chem. Ztg.*, XXII., 690). The process depends on the reduction to NH_3 by $Fe(OH)_2$ and metallic Fe. 1 gm. of the nitrate to be tested in 130 cc. water, receive the addition of 30 cc. NaOH solution (Sp. Gr. 1.33) and 40 gms. cryst. $FeSO_4$. The mixture is distilled slowly from a flask into standard acid. The operation is usually complete in 30 minutes. The vapor coming over when it is presumed to be complete, should, however, be tested. Tartrates interfere with the reaction, chlorides, sulphates and acetates do not. Phosphates will interfere, but this may be obviated by adding sufficient

$CaCl_2$ to give $Ca_3(PO_4)_2$ with the P_2O_5 present. The NaOH is then added with agitation until an excess is present. The mixture is made up to 170 cc. and the operation conducted as described.

Qualitative for Hydrogen Peroxide. Barralet (*Ch. News.*, LXXIX., 136). H_2O_2 quickly oxidizes the pale blue (Everitts Salt) product of the reaction between ferrous salt and ferrocyanides to "Prussian blue." Other oxidizing agents as $K_2Cr_2O_7$, $K_2Mn_2O_8$ or $Ca(ClO)_2$ cease to act at far smaller degrees of dilution. 1 cc. of a solution of one part of H_2O_2 in 165000 parts of water will show the reaction plainly.

BOOK REVIEWS.

Manual of Assaying. By WALTER LEE BROWN. E. H. Sargent & Co., Chicago, 1899. 8vo. 551 pages, Cloth, $2.50.

The present (eighth) edition presents few differences from its predecessors. In the preface recognition is given to Dr. Chandler for the assay tons system, which the author justly characterizes as "deserved if delayed," inasmuch as it has been in use in America for more than thirty years.

The book is intended for those who wish to learn assaying without any previous training or knowledge of chemistry, and is necessarily somewhat of the character of a receipt book. Methods are given with great detail as to manipulation, but in no case are reasons or reactions given; methods are pronounced inaccurate, but the cause of the losses not mentioned.

Part I. One hundred and seventy-seven pages are devoted to apparatus and reagents, and contains numerous illustrations of apparatus, including beakers, funnels, anvils, shears, etc.

Part II., the main portion of the book. One hundred and sixty-one pages describe the assay of gold and silver ores, copper ores and lead ores.

The part on ores of gold and silver contains much valuable information in regard to manipulation, and some useful charges, taken largely from Aarons' Assaying, but no mention of such recent methods as the "wet assay" of copper mattes for gold and silver, and the corrected assay of rich argentiferous material, which have attracted so much attention of recent years.

Under lead ores the preference is given to the cyanide method, which is contrary to the experience of most assayers.

The Appendix, 184 pages, contains descriptions of the electrolytic assay for copper; Amalgamation and Chlorination Assays; Gold, Silver and Base Bullion Assays; Tin Assays. Also many tables of numerals, weights, etc.

The detailed descriptions of scorification, cupellation, etc., are excellent, and the description of apparatus, while long, is undoubtedly useful for those who contemplate purchasing an outfit. Viewed from a scientific standpoint the book is disappointing and regards an assayer on a par with a skilled laborer rather than a chemist. It is well printed and of convenient size. E. H. M.

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All Graduates,	1172
Members of Alumni Association (all grades),	550
Associates,	17
Honorary Members,	8
Life Members,	28
Other Graduates,	501

(Revised to January 1, 1899.)

OFFICER

CONSTITUTING THE

BOARD OF MANAGERS

OF

The Alumni Association of the Schools of Science

OF

COLUMBIA UNIVERSITY.

1899.

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HOWARD VAN SINDEREN, '81.

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Columbia University, N. Y.

Secretary,

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Columbia University, N. Y.

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Columbia University, N. Y.

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EDMUND H. MILLER, '91.	IV.	JOHN SEWARD, '95.

NOTE.—Correspondence concerning dues and other clerical details of the work of the Association may be conveniently addressed to MR. FRANCIS W. HOADLEY, Assistant to the Secretary and Treasurer, No. 12 West 31st St., New York City.

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DELEGATES TO ALUMNI COUNCIL.

F. R. HUTTON,	1899
HOWARD VAN SINDREN,	1900
W. B. PARSONS,	1901
WM. ALLEN SMITH,	1902
D. L. R. DRESSER,	1903

LIST No. 1.

Contains the names of all graduates and Members of the Alumni Association grouped by classes from the beginning. The details as to residence and Professional Occupation are given in the second or alphabetical list for convenient reference.

(Revised to January 1, 1899.)

CLASS LIST

OF

GRADUATES AND MEMBERS

OF THE

ASSOCIATION OF THE ALUMNI.

[NOTE.—Where the name is followed by a date, it denotes that the person is no longer living, and the date is the year of the death.]

1867.

Adams, J. M., 1892.
Bridgham, S. W.
Bronson, E. S.
Brown, F. G.
Church, J. A.
Cornwall, H. B.
Giddings, E. E.
Gracie, C. K., 1891.
Hale, A. W.
Harding, G. E.*
Harmer, T. H.
Heath, F. M. (formerly Petit),
Tuttle, W. W.
Van Lennep, D.

1868.

Barnard, A. P.
Baxter, G. S.
Carson, J. P.
Chester, A. H.
Coursen, G. H.
Geer, G. J., Jr.
Hanna, G. B.
MacMartin, A., 1881.
Melliss, D. E.*
Moffatt, E. S., 1893.
Parsons, G. H.
Pennington, J. P.*
Pister, W.
Platt, C. S.
Robertson, K.
Shack, A. P.
Schermerhorn, F. A.
Smith, L.
Smith, W. A.
Stalknecht, F.
Van Arsdale, W. H.
Wheeler, M. D., 1889.

1869.

Blossom, T. M., 1876.
Bruckman, F.
Campbell, A. C.
Delafield, A. F.*
Hooker, W. A.
Huntingdon, C.
Irving, R. D., 1888.
Jenney, W. P.
Munroe, H. S.
Nettre, L. R.
Newton, H., 1877.
Potter, W. B.
Randolph, J. C. F.

1870.

Haight, O., 1891.
Ingersoll, W. H.
Knapp, J. A.
Lilienthal, J. L., 1893.
Lindsley, S.
Parrot, E. M.
Terhune, R. H.
Van Wagenen, T. F.
Waller, E.

---

* Associate.

1871.

Fales, W. E. S.
Goldschmidt, S. A.
Gordon, J.
Ricketts, P. de P.
Riggs, G. W.
Roberts, G. S.
Robertson, R. S., Jr.

1872.

Austen, P. T.
Jenney, F. B., 1876.
McDowell, F. H.
Sloane, T. O'C.
Wendt, A. F., 1893.

1873.

Canfield, F. A.
Colton, C. A.
Mott, H. A., 1896.
Webb, H. W.
Williams, J. T., Jr.

1874.

Allen, C. S.
Benedict, W. de L.
Cameron, J. G. M., '89.
Ledoux, A. R.*
Lillie, S. M.
Murray, G.
Olcott, E. E.
Rees, B. F.
Rhodes, F. B. F.
Williams, F. H.

1875.

Ihlseng, M. C.
Iles, M. W.
Jackson, C. E.
Joy, D. A., 1888.
Lamson, R. S., 1876.
Leavens, H. W.
Macy, A., 1891.
Noyes, W. S.
Pfister, P. C.
Putnam, B. T., 1886.
Rees, J. K.
Rolker, C. M.
Russell, S. H., 1889.
Stewart, H.
Thompson, M. S.
Tucker, J. H.
Vanderpoel, F.
Wells, J. S. C.
Wetmore, E. A.
Wright, A. A.

1876.

Austin, T. S.
Bruen, F. E., 1884.
Cornwall, G. R.
Craven, F. C., 1890.
Foote, H. C., 1888.
Garrison, E. H.
Gratacap, L. P.
Hall, R. W.
Hamilton, S., Jr.
Holbrook, F. N.
Hoyt, W. L.
Hunt, F. F.
Hutton, F. R.
King, C.
Lord, N. W.
Love, E. G.
Maghee, J. H.
Morewood, H. F.
O'Grady, J. W., 1890.
Randolph, J. F.
Ross, W. C.
Schneider, A. F.
Tilden, G. C.
Van Blarcom, E. C.
Walbridge, A. C., 1892.
Wardlaw, J. R., 1891.

1877.

Barros, L. de S.
Barus, C.
Beard, J. T.
Behr, E.
Buckley, C. R.
Cady, L. B.
Canfield, A. C.
Cauldwell, J. B.
Clark, H. G., 1881.
Colby, C. E., 1897.
Constant, C. L.
Cornell, G. B.

* Associate.

Floyd, F. W.
Helleberg, F. S., 1883.
Hildreth, W. E.
Ihlseng, A. O.
Jordaõ, J. N. P.
Kelly, W.
Mackintosh, J. B., 1891.
Martin, E. W.
Murphy, J. G.
Nichols, R.
Norris, D. H.
Priest, J. R., 1880.
Radford, W. H.
Reed, S. A.
Rogers, C. L.
Sage, E. E.
Smeaton, W. H.
Smythe, R. M.
Teacher, A.
Van Boskerck, R. W.
Waterbury, C. R.

1878.

Adams, W. J.
Benjamin, M.
Blydenburgh, C. E.
Booraem, R. E.
Brinkerhoff, G. C.
Butler, W. P.
Cushman, A. R.
Davis, J. W.
Devereux, W. B.
Downing, O. P.
Drummond, I. W.
Eliot, W. G.
Fernekes, A., 1884.
Haas, H. L.
Hasegewa, Y.
Hodgse, H. A., 1883.
Holden, E. H.
Hollis, W.
Johnson, E. M.
Johnson, G. H.
Karr, C. P.
Lawrence, B. B.
Lyman, F.
Matsui, N.
McCulloh, E. A.
Morewood, G. B.
Morris, G. W., 1895.
Munsell, C. E.
Murphy, H. M.
Nambu, K.
Newberry, S. B.
Noyes, J. A.
Olmstead, O. F., 1881.
Owen, F. N.
Palmer, C. E.
Parker, R. A.
Pazos, V. F.
Perry, N. W.
Strieby, W.
Willis, B.

1879.

Bolton, R.
Britton, N. L.
Cloud, L. G.
Cornwall, H. C.
DeLuze, L. P.
Eastwick, G. S.
Haffen, L. F.
Harker, C. S.
Hathaway, N.
Hollerith, H.
Hollick, C. A.
Johnson, I. B.
Johnston, R. A., 1895.
Koch, E. C., 1898.
Leggett, T. H.
Ludlow, F.
Marsh, C. W., 1896.
Mathis, T. S.
Mayer, R. E.
Merwin, H. J.
Milliken, G. F.
Munroe, O. M.
Neftel, K.
Nesmith, J.
Noble, C. M.
Reed, W. B. S.
Rhodes, R. D.
Rutherfurd, F. M.
Sheldon, G. H., 1889.
Starr, H. F.
Stewart, F. B., 1879.
Stone, G. C.
Suydam, J. R.
Williams, G. W.

1880.

Beebe, A. L.
Benjamin, F. P., 1893.
Browning, F. D., 1885.
Browning, J. H. B.*
Brugman, W. F.
Butler, N.
Churchill, A. D., 1896.
Clark, E. P.
Elliott, W.
Engel, L. G.
Francke, R. O.
Garlichs, H.
Greene, W. U.
Greenleaf, J. L.
Hallock, A. P.
Hendricks, H. H.
Hooper, L. M.
Hopke, T. M.

* Associate.

Hudson, E. H.
Klepetko, F.
Kunhardt, W. B.
Mattison, J. G.
Meissner, C. A.
Merritt, J. H.
Navarro, J. A.
Parker, A. McC.
Parks, J. R.
Robinson, H. A.
Ruttman, F.
Singer, G.
Singer, G. H.
Smalley, W. A., 1886.
Smith, M.
Tonnelè, T.
Torrey, C. H., 1895.
Walker, J., Jr.
Wheeler, H. A.

1881.

Andresen, C. A.
Aschman, F. T.
Bleecker, C. P.
Braschi, V. M.
Bush, E. R.
Chazal, P. E.
Colby, A. L.
Curtis, C. G.
Douglas, E. M.
Dunham, E. K.
Elliott, A. H.
Furman, H. V. F.
Griswold, W. T.
Hemmer, F. A.
Judd, C. B.
Leary, D. J.
LeBoutillier, C.
Ledoux, A. D.
Little, W. P.
Meserole, W. M.
Neymann, P.
O'Connor, M. J.
O'Connor, T. D.
Pitkin, L.
Raymer, G. S.
Richmond, W. T.
Roberts, A. C.
Sawyer, C. P.
Share, W. W.
Starr, C. D.
Stearns, T. B.
Swain, A. E.
Tuttle, E. G.
Van Sinderen, A. H.
Vulté, H. T.
Williams, W. F.
Wiechmann, F. G.
Wilson, H. M.

1882.

Calman, A.
Conant, T. P., 1891.
Cooper, W. H.
Crocker, F. B.
Dougherty, O. V., 1889.
Downes, S. B., 1895.
Downs, W. F.
Emrich, A. F., 1893.
Falk, D. B.
Feuchtwanger, H.
Fitch, C. L.
Going, C. B.
Hill, W.
Illig, W. C., 1894.
Joüet, C. H.
Mesa, A. E.
Moses, A. J.
Oothout, E. A., 1894.
Page, W. S.
Parsons, W. B.
Payne, C. Q.
Porter, J. B.
Powers, C. V. V.
Sands, F.
Shumway, W. A., 1892.
Staunton, W. F.
Stockwell, N. S., 1888.
Toucey, D. B.
Traphagen, F. W.
Vondy, R. H.
Wainwright, J. H.
Wanier, A. G.
Ward, N. R.
White, W. S.
Wilson, W. A.
Wittmack, C. A.
Young, E. L.

1883.

Abeel, G. H.
Adams, R.
Ayestas, A.
Balch, S. W.
Banks, J. H.
Bardwell, A. F.
Brereton, T. J.
Brewster, H. D.*
Bullman, C.
Carrére, J. M.
Channing, J. P.
Endicott, G., 1889.
Ferrer, C. F.
Ferris, J. C.
Fiallos, E. C.
Haasis, D. F.
Humbert, W. S.
Lilliendahl, A. W.

* Associate.

MacTeague, J. J.
McKenna, C. F.
Oxnard, J. G.
Painter, G. E.
Parraga, C. F.
Peele, Robert.
Powell, F.
Randolph, E.
Renault, G.
Rich, J. M.
Richardson, J. C.
Ridsdale, T. W.
Suter, G. A.
Tibbals, G. A.
Tower, A. E.
Walker, A. L.
Weed, W. H.

1884.

Adams, W. C.
Alden, H. C.
Baldwin, W. M.
Barnard, E. C.
Barratt, E. G.
Bodelsen, O.
Brinley, J. R.
Bryce, W.
Buckingham, F. E.
Burritt, W. W.
Corcoran, J. T.
Del Calvo, F.
Duncan, W. P., 1889.
Dusenberry, W. L.
Easton, L. C.
Fahys, G. E.
Fitch, J. H.
Fitzgerald, G. E.
Fowler, S. S.
Glover, C. G., 1888.
Gosling, E. B.
Griffin, S. P.
Gross, L. N.
Horn, J. T.
Kemp, J. F.
Lamb, A. J.
Luttgen, E.
McGenniss, J. W., Jr., 90.
McKim, R. A.
McLoughlin, C. S.
Miller, C. W.
Moeller, W., 1897.
Moran, D. E.
Morgan, W. F.
Mulford, R.
Napier, A. H., 1895.
Newberry, W. E., 1898.
Newbrough, W.
Nolan, T.
Northrop, J. I., 1891.
Nye, A. C.
Painter, C. A.
Pearis, C. F.
Pellew, C. E.
Post, A. S.
Powers, L. J.
Proctor, W. R.
Reckhardt, D. W.
Roeser, F.
Rood, R. G.
Rowland, C. B.
Rupp, P., Jr.
Schöney, E., 1888.
Sherman, F. D.
Slack, C. G.
Smedberg, H. A.
Snook, T. E.
Speyers, C. L.
Tibbals, S. G.
Value, B. R.
Walbridge, F. K.
Wood, G. E.

1885.

Amy, E. J. H.
Barkley, H. F., 1895.
Bemis, F. P.
Brennan, A. J.
Bush, W. F.
Cary, G.
Clark, F. S.
Cozzens, H.
Crowell, C. B.
Detwiller, C. H.
Doolittle, C. H.
Dwight, A. S.
Eddie, E. C.
Engelhardt, E. N.
Graff, C. E.
Hart, B.
Hawkes, E. McD.
Hildreth, R. W., 1895.
Hollis, H. L.
Huntington, F. W.
Ingram, E. L.
Johnson, A. G.
Lacombe, C. F.
Lee, G. B.
Mannheim, P. A. L.
Marié, L.
Merrill, F. J. H.
Meyer, H. H. B.
Miller, C. L.
Moldehnke, R. G. G.
Noble, L. S.
Norris, R. V. A.
Page, G. S.
Pierce, H. N.
Polledo, Y. Y.
Sanders, W. E.
Shope, H. B.
Starek, E.
Struthers, J.
Thomas, F. M.
Titus, W. H.
Van Cortlandt, E. N.
Watson, F. M.
Whitman, E. P.
Wiltsie, E. A.
Woolson, I. H.

1886.

Agramonte, E.
Agramonte, J. C.
Bell, H. M., Jr.
Berry, W. G.
Casey, E. P.
Conant, H. D.
Edwards, R. M.
Frankfield, E.
Good, G. McC. H.
Horne, W. D.
Howe, F.
Janeway, J. H.
Jenks, A. W.
Kissam, H. S.
Lederle, E. J.
Lee, H. C.
Newhouse, E. L.
Norton, L. H.
Ormsbee, J. J.
Osterheld, T. W.
Peck, S. B.
Porter, H. H., Jr.
Ryon, A. M.
Spooner, A. N.
Stodder, R. H., 1887.
Stuart, W. H.
Thompson, H. C.
Trowbridge, S. B. P.
Van Brunt, A. H.
Van Nardroff, E. R.
Wallace, W. J.
Wheatley, J. Y.
Wilson, C. E.

1887.

Aldridge, W. H.
Appleby, W. R.
Bellinger, H. P.
Bien, J. R.
Burns, A. L.
Burns, E. Z.
Butler, W. C.
Church, E. D.
Cole, H. M.
Congdon, E. A.
Cox, J. S., Jr.
Darwin, H. G.
Davis, C. H.
Donnell, H. E.
Ferguson, W. C. A.
Gage, S. E.
Goldsmith, B. B.
Gudeman, E.
Heinsheimer, A. M.
Huntting, H. O.
Jacobs, D. M.
Jacobs, S. J.
Jeup, B. J. T.
Lahey, J.
Lahey, R.
Luquer, L. McI.
Lusk, G.
MacKaye, H. S.
Mannheim, H. C.
Marsh, J. R.
Middleton, J.
Moeller, R.
Muller, G.
Nichols, H. P.
Primelles, J. A.
Restrepo, C. C.
Rice, G. S.
Rowland, G.
Rutherford, L. H.
Schieffelin, W. J.
Seligman, J. G.
Simonds, F. M.
Slade, R. E.
Stanton, F. McM.
Staunton, J. A., Jr.
Stevens, A.
Tower, F. W.
Trask, G. F. D.
Tyler, W. L.
Warner, J. L.
Wels, P. O.
Wertheimer, L.

1888.

Allen, R. L.
Appleby, J. S.
Baker, G. L.
Bartlett, F. R.
Bechstein, C. A.
Beckwith, C. E.
Berry, G.
Colt, S. B.
Comstock, C. N.
Dodge, F. D.
Dodsworth, W. A.
Dow, A. W.
Fisher, W.
Frank, J. W.
Gardner, W. D.
Herbert, O. B.
Hopke, F. E., 1890.
Jones, W. D.
Koen, J. J.
Lenox, L. R.
Lipps, H., Jr.
McIlvaine, A. R.
Maclay, J.
Miller, R. P.
Morgan, J. L.
Munoz del Monte, A. C.
Parker, O. B., 1891.
Parsons, H.
Percival, G. S. 1892.
Perkins, T. S.
Schumann, C. H.
Shriver, H. T.
Smith, F. P.
Smyth, C. H., Jr.
Stoughton, A. A.
Taylor, J. B.
Tucker, A.
Von Dyck, F.
Van Volkenburgh, E.
Volckening, G. J.
Wampold, L.
Ward, D. W.

1889.

Atha, H. G.
Berry, G.
Brown, R. G.
Cramer, S. W.*
Cromwell, J. W.
Denton, F. W.
Dresser, D. LeR.
Eastwick, E. P.
Eilers, K. E.
Ellis, A. V. H.
Escobar, F.
Fearn, P. LeR.
Fowler, A. C.
Freedman, W. H.
Gifford, S. D.
Griffith, V. C.
Griggs, W. E.
Guiterman, E. W.
Harrington, T. H.
Harris, F.
Heinze, F. A.
Holt, M. B.
Ives, A. S.
Joplin, R. F.
Luquer, T. T. P.
Mahony, A. S.
Mapes, C. H.
Mason, C. S., 1889.
Massa, C. G.
Matthews, C. T.
Monell, J. T.
Mosley, R. K.
Oseransky, I. H.
Piez, C.
Post, A. Van Z.
Preston, W. E.
Provost, A. J., Jr.
Provot, G.
Raymond, R. M.
Raynor, R.
Rogers, O. L.
Schroder, J. L.
Skidnore, S. T.
Small, F. M.
Smith, A.
Smith, F. M.
Stoughton, C. W.
Waters, G. S.
Wedekind, E. H.
Weekes, E. F., 1893.
Weeks, W. H.
Whitlock, H. P.

1890.

Andrews, S. W.
Beckwith, G. A.
Behlen, H.
Betts, R. T.
Black, A. L.
Blake, E. M.
Book, D. E.
Bradley, S. R.
Buckland, W. A.
Cairns, F. I.
Carson, J.
Clark, D. L.
Clayton, W. R.
Colton, F. G.
Connell, H. R., 1895.
Coykendall, T. C.
Davis, W. M.
Deghueé, J. A.
Douglas, J. S.
Ferguson, G. A.
Fisher, L. W.
Foyé, A. E.
Gildersleeve, A. C.
Gould, E. L.
Gudewill, C. E.
Hart, C. H.
Hewlett, J. M.
Hicks, G. J., 1891.
Hinman, B. C.
Hooper, F. C.
Hoyt, J. S.
Hurlbut, E. D., Jr.
Jarmulowsky, M.
Jones, J. T.
Kohn, R. D.
Korn, L.
Levy, A. L.
Lichtenstein, E. G.
Lowndes, W. S.
McKleroy, W. H.
Mann, H. B.
Massa, L. F.
Meikleham, T. M. R.
Montenegro, M. R.
Parker, H. C.
Pearce, R.
Pelton, H. C.
Portuondo, J.
Post, W. S.
St. John, T. M.
Steers, J. R.
Thorne, W. L.
Warren, C. P.
Welch, A. McM.
Welsh, H. F.

1891.

Anderson, Geo.
Bliss, C. P.
Bookman, S.*
Blossom, F.
Boecklin, W.
Boyd, R. C.
Brosnan, F. X.
Cristy, E. B.
Dunn, G. S.
Eberhardt, W. G.
Goodwin, E.
Hawley, J. F.

* Associate.

Holter, N. B.
Hornbostel, H. F.
Keeler, F. S.
Kinsey, F. W.
Langthorn, J. S.*
Leary, G.
Lilliendahl, F. A.
Livingston, A. R.
Mahl, J. T.
Mann, C. R.
Miller, E. H.
Mora, M. L.
Owens, R. B.
Raymond, A.
Skinner, E.
Strout, W. A.
Thomas, F. C.
Totten, G. O., Jr.
Tuska, G. R.
Warren, L.
Watson, R. B.
Wiener, W.

1892.

Ansbacher, L. A.
Anthon, A.*
Bergen, C. H.
Bolles, R.
Burden, H., 2d.
Casamajor, G. H.
Clark, E.*
Clarke, W. C.
Covell, E. C.
Curtiss, C. C.
Dolan, C. F.
Dufourcq, E. L.
Durham, E. B.
Dutcher, B. H.
Fenner, C. N.
Friedman, S.
Gillette, H. P.
Granger, A. D.
Harrison, N.
Hay, A.
Herckenrath, W. A.
Jackson, O.
Kletchka, J. J.
Knox, C. E.
Livingston, G.
Longacre, L. B.
Lord, F. R.
McIlhiney, P. C.
McKinlay, J. B.
Meisel, F. C. A.
Merz, E.
Parmly, C. H.
Pierce, F. E.
Reckhart, G. F.
Reese, W. W.
Ries, H.
Rosenthal, A.
Savage, S. M.
Southard, G. C.
Temple, S. J.
Towart, J.
Van Ingen, D. A.
Werner, H. C.
White, R. D.
Windecker, C. N.
Windolph, A. P.

1893.

Agelasto, M. A.
Agramonte, I. E.
Aldrich, C. H.
Ayers, W. C.
Behrmann, G. W.
Bossange, E. R.
Brooks, W. F.
Canfield, M. C.
Clark, G. H.
Covell, W. S.
Foster, R. G.
Gonzalez, A.
Gregory, L. E.
Hankinson, A. W.
Harte, C. R.
Haskell, H. G.
Hoyt, R.
Hume, F. T.
Hyde, F. S.
Jones, J. Elmer.
Kurtz, E. L.
Langmuir, A. C.
Liebmann, A.
McKee, H. S.
Macy, V. E.
Malukoff, A. J.
Matthew, W. D.
Newton, T. M.
Oakes, J. C.
Pederson, F. M.
Pomeroy, W. A.
Post, R. B.
Prince, A. D.
Provot, F. A.
Putnam, B. R.
Reynolds, M. T.
Robinson, F. G.
Schroter, G. A.
Smith, H. A.
Thompson, S. C.
Tilghman, H. A.
Tuttle, W.

1894.

Acken, B. A.
Barnett, L. K.
Black, A.
Bogert, M. T.
Chapman, A. W.
Clark, L.

* Associate.

Cokefair, F. A.
Emery, H. G.
Fellows, W. K.
Folger, E. P.
Frisbee, H. D.
Fuentes, P.
Greene, D. J.
Hamilton, F. C.
Hanson, R. C.
Hass, E. F.
Jacobs, H. A.
Joffe, M.
Jones, E. M.
Kastner, J. C.
Leeming, T. L.
Libaire, E. W.
McNeil, C. R.
Masters, H. K.
Messiter, E. H.
Mears, G. K.
Morris, B. W., Jr.
Murchison, K. M.
Munroe, M.
Osterberg, M.
Parsons, H. A.
Perrine, G.
Pope, J. R.
Prince, J. L.
Rennard, J. C.
Rittenhouse, C. T.
Searle, C. D.
Seldner, R.
Self, E. D.
Sherman, G. F. G.
Smith, W. F.
Steinam J. L.
Stratton, Alex.
Taintor, W. N., 1898.
Tennille, G. F.
Tompkins, J. A.
Vail, L. H.
Vanderbilt, W. D.
Vatable, J. J.
Walker, H. V.
Ware, F. B.
Westervelt, W. Y.
White, T. G.

1895.

Alexander, J. A.
Andrews, W. C.
Archer, G. F.
Albertson, A. H.
Barnett, L. H.
Bayles, F. P.
Baldwin, D. H.
Binion, J.
Benedikt, V. M.
Bijur, J.
Buck, H. W.
Bultman, H. D.
Candler, D. W.
Carter, B. P.
Coykendall, E.
Cox, E. V.
Dobbins, M.
Drasel, C.
Durham, H. W.
Dewey, F. H.
Evans, I. N.
Fintel, E. A. von, Jr.
Fletcher, G. W.
Foerster, D.
Fox, M. J.
Gottsberger, B. B.
Gartensteig, C.
Grace, F. J. M.
Herzig, C. S.
Huntoon, L. D.
Horton, C. F.
Hadden, H. S.
Jarman, Z. H.
Johnstone, W. B.
Jobbins, F. H.
Janes, E. H.
Kirby, G. T.
Kraemer, H.
Leo, R. L.
Lum, C. H.
McKinlay, W. B.
Miller, S. O.
Moisseieff, L. S.
Moses, P. R.
Moeller, E. J.
Mulliken, H. B.
Natkins, I.
Ormsbee, A. F.
Peugnet, C P.
Pinkham, H.
Portuondo, J. M.
Pell, F L.
Peppmüller, R H.
Perrin, H. C.
Pilcher, L. F.
Reeve, F. C.
Riker, C. L.
Spaulding, M. B.
Shattuck, L. R.
Shrady, C. D.
Sutton, F.
Stewart, J. H.
Schell, R. M.
Seward, J.
Thomas, E. H.
Tucker, S. A.
Walker, F. W.
Whiting, L.

1896.

Arden, J. L.
Auryansen, F.
Benoniel, S. D.
Burrill, P. M.
Carney, E. J.
Clark, A. J.
Comstock, F. L.
Darrach, J. M. A.
Derleth, C., Jr.

Dowie, H.
Franklin, L. M., Jr.
Godley, R. D.
Goldsmith, G.
Hawks, H. D.
Heye, G. G.
Holden, E. C.
Hyatt, C. E.
Hyde, H., St. J.
Lowenstein, J.
McCaffery, R. S.
McConway, W. L.
MacGahan, P.
MacGregor, D.
Hesselbach, C. V.
Metzger, A.
Monell, A., Jr.
Montgomery, H. P. A.
Morse, G. T.
Necarsulmer, E.
Of, C.
Painter, R. K.
Palmer, G. Q.
Parker, R. A.
Pemoff, J.
Perry, C. L.
Prosser, H. A.
Raymond, W. O.
Regan, G. W.
Riedel, A. E.
Rodenburg, C.
Serber, D. C.
Sergeant, E. M.
Shire, E. I.
Slichter, W. I.
Stern, H.
Tachau, W. G.
Thyng, W. S.
Toch, M. B.
Tompkins, E. De V.
Townsend, S. G. F.
Tubby, J. T., Jr.
Uhling, W. C.
Van Benthuysen, B.
Van Gelder, A. P.
Van Vleck, J., Jr.
Wells, D. C.
Witherell, C. S.
Woodruff, G. W. L.

1897.

Adams, E. K.
Barnes, W. C.
Bates, P. A.
Baxter, D. E.
Bellman, J. J.
Bishop, R. R.
Boehm, G. A.
Boerner, E. C., Jr.
Brown, A. M.
Burroughs, H. S.
Clark, J. H.
Congdon, H. W.
Coykendall, F.
Chatain, H. G. F. J.
Clark, C. M.
Collins, C. L., 2d.
Crampton, S. H.
Davidson, W. S.
Emanuel, L. V.
Force, D. N., Jr.
Farmer, A. S.
Fulton, C. H.
Gill, A. W.
Goodridge, J. W.
Gotthelf, A. H.
Haldy, G. F.
Hildburgh, W. L.
Holbrook, F. M.
Humphreys, J. B.
Herz, H.
Koch, R.
Kaufmann, E.
Kilian, W. G.
Knox, N. B.
Loewenthal, M.
McLean, J. M.
MacMullen, C. W.
McClelland, J. B.
Maben, J. C., Jr.
Madden, J. H.
Manheims, L. R.
Magalhaes, G. W.
O'Reardon, I.
Perkins, S.
Prosser, H. A.
Ralph, H. P.
Rogers, C. E.
Riederer, E. J.
Rappold, G. W.
Sayres, J. H.
Schlecht, W. W.
Stander, I.
Stout, J. S., Jr.
Smith, O. B., Jr.
Taylor, A. S. G.
Tibbals, R. G.
Van Deventer, C.
Van Dyck, W. V. B.
White, L.
Waldenberger, C. A.

1898.

Anthon, G. C.
Arendt, M.
Beadel, H. L.
Beatty, A. C.
Bennett, G. L.
Bentley, W. A.
Bostwick, W. A.
Brackett, G. S.
Brown, H. D.
Buck, V. B., Jr.
Burns, W. G.
Burnside, C. H.
Campbell, A. J.
Caswell, K. L.
Chibas, L. F.
Conover, J. T.
Daly, E. H.
De Coppet, T.
Dunn, A. D.
Eckerson, C. H.
Ferguson, G.
Foote, E., Jr.
Geppert, R. M.
Goodman, J.
Gotschall, L.
Gumaer, A. H.
Gunn, G. B.
Haight, C. S.
Haskell, G. M.
Hill, R. F., Jr.
Hodgson, E. H.
Hutchins, G. L.
Jones, J. E.
Jones, W. P.
Joseph, T. H.
Judson, H. C.
Kipp, B.
Krumb, H.
Le Prince, J. A. A.
Levine, E. J.
Lewis, C. MacK.
Livingston, J., Jr.
Lobo, G.
Lowther, C. M.
Lucas, G. L.
Lydecker, I. S.
McClure, W. J.
McClellan, H.
Magruder, H. S.
Martin, L. T.
Mason, F.
Menline, I.
Mitchell, H. B.
Mortimer, H. C., Jr.
Newman, M. L.
O'Connor, J. W.
O'Connor, W. A.
Otto, C. L.
Parsons, W. E.
Pattberg, O. F.
Peck, T. B., Jr.
Raisman, A. I.
Reyna, J. E.
Ros, J. P.
Ropes, Wm.
Saunders, G. C.
Schimmel, J., Jr.
Sessinghaus, G.
Smith, W. A., Jr.
Sturgis, E. B.
Sutro, H. H.
Tatlock, J. L.
Thomas, W. S.
Titcomb, H. A.
Trapote, R.
Tudor, W., Jr.
Van Voorhis, B. W., 2d.
Vredenburgh, W., Jr.
Ware, Arthur.
Watson, William.
Weeks, R. D.
Wolff, H. H.

LIST No. 2.

This list embraces the members of the Alumni Association of the Schools of Science of Columbia University under the Constitution of that body. It is urged that all graduates of the school should list themselves under this group. Names not found here are grouped in List No. 3, which includes graduates who are not also members. All graduates are requested to try to make and keep this list correct and accurate.

(Revised to January 1, 1899.)

MEMBERS

OF

The Alumni Association of the Schools of Science

OF

COLUMBIA UNIVERSITY.

A.

ABEEL, GEORGE HOWARD, E.M., ... 1883.
Box 642 Hurley Iron Co., Wis. Also 5 East 124th St., New York City.

1883–84, Chemist Iron Cliffs Co., Negaunee, Mich. 1885–88, Assistant Manager Cliffs Co., Negaunee, Mich. 1886–1887, Supt. Negaunee Gas Light Co., Mich. 1888–89, Manager Ironton Iron Mining Co., Bessemer, Mich. 1888–89, Agent Pilgrim Mining Co., Bessemer, Mich. 1889, Supervisor Bessemer Township, Gogebic Co , Mich. 1889–92, Agent Ruby Iron Mining Co., Bessemer, Mich. 1888 to 1895, General Manager Montreal River Iron Mining Co., Hurley, Wis. 1892 to 1894, Vice-President First National Bank, Hurley, Wis. 1892 to date, Vice-President Wisconsin Mining Supply Co., Hurley, Wis. 1893, Vice-President and General Manager Section 33 Iron Mining Co., Hurley, Wis. 1894, Consulting Engineer Newport Mining Co., Supervisor, Town of Vaughn.

ADAMS, ERNEST K., PH.B. (Yale), E.E., M.A., . . 1897.
455 Madison Avenue, New York, N. Y.

ADAMS, RANDOLPH, E.M., ... 1883.
425 Seventh Avenue, Clinton, Iowa.

1883–85, Chemist and Engineer in Dept. for Testing Materials ; Erie Railway, Susquehanna, Pa. 1886, Foreman of Mill—dry crushing, chlorination and amalgamation—for Silver King Mining Co., Pinal, Ariz. 1887–88, Assistant Superintendent and General Superintendent for the Silver King Mining Co., Silver King, Ariz. 1889–91, went to New South Wales, Australia, on two-years' engagement as General Manager of Webb's Silver Mining Co., Ltd., Sydney. 1891–95, General Manager of the "Central" Broken Hill Mine, New South Wales ; for the Central Broken Hill Silver Mining Co., of Sydney and Melbourne. During above engagement was also General Manager for the two adjoining properties, viz : The Central Blocks Silver Mining Co., Ltd., and the North Central Silver Mining Co., N. L., of Sydney. 1895-97, General Mining Manager, at Broken Hill, for the Sulphide Corporation (Ashcroft's Process), Ltd., of London and Melbourne. During engagement in Australia also made special mining and treatment reports

on various silver, gold and copper properties, throughout Queensland and New South Wales.

ALDRIDGE, WALTER HULL, E.M., ... 1887.
Trail, British Columbia.
And *for mail*, 203 Montague Street, Brooklyn, N. Y.

Beginning July, 1887, Assayer at Colorado Smelting Co., Pueblo. At different times, Chemist of Colorado Smelting Co., Pueblo. August, 1890-91, Assistant Superintendent and Metallurgist of Colorado Smelting Co., Pueblo. Assistant Manager United Smelting and Refining Co. 1893 to November, 1897, Manager United Smelting and Refining Co., E. Helena, Mont. November, 1897, accepted position with Canadian Pacific Railway as Consulting Mining Engineer and Manager of their Smelting Works.

ALLEN, ROBERT LAWRENCE, A.M., E.M., . . . 1888.
102 Cambridge Place, Brooklyn, N. Y.

AMY, ERNEST JULIUS HYACINTHE, A.B., E.M., . . 1885.
General Manager, San Juan S. and M. Co., Durango, Colo.

1885-86, Chemist and Assayer at works of the San Juan and N. Y. M. and S. Co., at Durango, Colo., with the exception of three months' professional visit to Old Mexico. 1886-87, Assistant Manager of the San Juan and N. Y. M. and S. Co., at Durango, Colo. 1887-88, Manager of the Hazleton Mountain Mining Co, at Silverton, Colo. 1888 to April 1, 1890, Assistant Manager of Works of the San Juan Smelting and Mining Co., at Durango, Colo. (The S. J. S. and M. Co. being formed by the consolidation of the S. J. and N. Y. M. and S. Co., of Durango, and the Hazleton Mt. Mfg. Co., of Silverton, Colo.) Since April 1, 1890. General Manager of the San Juan Smelting and Mining Co., at Durango, Colo.

ANDREWS, SAMUEL WAKEMAN, JR., PH.B., . . 1890.
35 W. Forty-second Street, New York City.

1890-91, Designing with Tiffany glass and Decorating Co., New York. 1891-98, member of firm Andrews, Waters & Sherwin.

ANDREWS, WM. C., E.E., ... 1895.
Assistant in Physics, Columbia University, New York City, and Hotel Margaret, Brooklyn, N. Y.

ANSBACHER, LOUIS ADOLPH, PH.B. . . . . 1892.
A. B. Ansbacher & Co., 4 Murray St., and 15 West 75th St., New York City.

ANTHON, ARCHIBALD, E.E. (Associate), . . . 1892.
13 West 35th Street, New York City.

APPLEBY, W. R., A.B. (Associate), ... 1887.
Professor of Mining and Metallurgy, School of Mining and Metallurgy, University of Minnesota, and 911 Fifth Street, S. E., Minneapolis, Minnesota.

ATHA, HENRY GURNEY, PH.B., A.M. (Williams), . 1889.
Care of The Benjamin Atha & Illingsworth Co., Harriston, and 89 Clinton Street, Newark, N. J.

AUSTEN, PETER TOWNSEND, PH.B., PH.D., . . 1872.

346 Broadway, New York City and 218 St. Johns Place, Brooklyn, N. Y.

1878-80, Assistant Professor of Analytical Chemistry, Rutgers College. 1880–89, Professor of General and Applied Chemistry, Rutgers College. 1891, Superintendent Manufactories of W. J. Matheson & Co., limited, Ravenswood, N. Y. 1892, General Manager, Ledoux Chemical Laboratory. 1893, Professor of Chemistry, Polytechnic Institute, Brooklyn, N. Y.

AUSTIN, THOMAS SEPTIMUS, E.M., ... 1876.

Chihuahua Mining Co., Chihuahua, Mexico.

1877–78, in Cuba as Chemist. 1879-80, Assayer Germania Smelting Co. 1880-90, Superintendent Rio Grande Smelting Co., Socorro. N. M.

B.

BALCH, SAMUEL WEED, E.M., ... 1883.

Box 333 Yonkers, N. Y., and 41 Wall St., New York City.

1883–84, Otis Elevator Co. 1884–86, Mowing Machines. 1886-89, Garvin Machine Co., Tools and Special Machinery. 1889 to date, General consulting practice as Mechanical Expert and Patent Attorney. Specialty, Difficult Mechanical Problems.

BALDWIN, WILLIAM M., PH.B. (Life Member), . . 1884.

New York and Boston Dyewood Co., 55 Beekman St., New York City, and Garden City, Queens Co., N. Y.

Since 1885, Chemist for the New York Dyewood Extract and Chemical Co, Since 1888, Vice-President of the above corporation, and Manager of same from 1892 to date.

BANKS, JOHN HENRY, E.M., PH.D., ... 1883.

104 John Street, New York City, and Boonton, N. J.

1883–85, Chemist with Ledoux & Ricketts, New York. 1885–91, Private Assistant to Prof. Ricketts, School of Mines, New York, in general analytical, metallurgical and mining engineering work. 1889-91, Hon. Fellow in Assaying, School of Mines. 1894 to date, in partnership with Prof. Ricketts, at above address, in general chemical, metallurgical and mining engineering work, with Ore Testing Works, at Waverly, New Jersey, for determining treatment of ores and examination of processes.

BARNARD, EDWARD CHESTER, E.M., ... 1884.

U. S. Geological Survey, Washington, D. C.

Assistant Topographer and at present Topographer in the United States Geological Survey, 1884-91. Have been engaged in mapping in Virginia, West Virginia and the mountains of East Kentucky. 1893, mapping Northern New York.

BARNETT, L. H., E.M., ... 1894.

Assayer of Enterprise Mining Co., Rico, Colo., and 295 Columbus Avenue, New York City.

1895, Field Assistant U. S. Geological Survey. 1896, Assistant Chemist Philadelphia S. & R. Co., Pueblo, Col. and Mining Engineering Enterprise Mining Co., Rico, Col. 1897, Mining Engineer, Enterprise Mining Co., Rico, Col.

BARRATT, EDGAR GRANT, C.E., ... 1884.

1601–3 Fisher Bldg., Chicago, Ill., and Kenilworth, Ill.

1884-88 Engineer for The Exhaust Ventilator Co. 1888 to date, President and Proprietor of the Exhaust Ventilator Co. 1891 to date, President and General Manager of the Variety Manufacturing Co. Fill the above positions at present and am consulting Ventilating and Heating Engineer. 1897, Manager of Fisher Building, Chicago.

BARUS, CARL, PH.D. (Associate), ... 1877.

Brown University, Providence, R. I.

BATES, PUTNAM A., E.E., ... 1897.

The Crocker-Wheeler Electric Company, Ampere, N. J., and 113 West 72d Street, New York, N. Y.

Electrical Engineer, with Crocker-Wheeler Elec. Co., from graduation to date.

BAYLES, FREDERICK P., E.M., ... 1895.

Steel Works, Pueblo, Colo., and 408 Main Street, Orange, N. J.

Chemist and Assayer for the Sonora Copper Co., Sonora, Old Mexico. First Assistant Chemist Steel Works of Colo., Fuel & Iron Co. 1897.

BEARD, JAMES THOM., E.M., C.E., ... 1877.

The International Correspondence School, 304 Webster Avenue, Scranton, Pa.

1879–80, Assistant Engineer, New York and Brooklyn Bridge. 1880–82, Assistant Engineer, C. B. and Q. R. R. 1882–83, Superintendent Smoko Hollow Mine, Avery, Ia. 1884–85, Assistant U. S. Dept. Min. Surveyor, Aspen, Colo. 1885–91, Engineer, Whitebreast Fuel Co., Ottumwa, Ia. 1891–92, Manager Miller Creek Land and Lime Co., Aspen, Colo. 1892–93, Secretary and Treasurer, Eldon Coal and Mining Co., Ottumwa, Ia. 1893–96, Iowa Mining Exchange, Ottumwa, Ia. 1892–94, Wrote Beard's *Ventilation of Mines*, published by John Wiley & Sons, New York City. 1896, Chief Instructor in Mining Engineering International Correspondence School, Scranton, Pa. 1898, Principal of the School of Mines International Correspondence Schools, Scranton, Pa.

BEATTY, ALFRED CHESTER, E.M., ... 1898.

3 East 9th Street, New York City.

BECHSTEIN, CHAS. A., ... 1888.

405 West End Avenue, New York City.

BEEBE, ALFRED L., PH.B., ... 1880.

Care of Alfred L. Brown, 170 Broadway, New York City.

1880–87, inclusive, Private Assistant to Prof. Ricketts, School of Mines, New York, in general analytical work, especially Mineral Analyses. Also Assistant in Assaying and Fellow in Chemistry, in 1881–87, inclusive. 1888–92, Assistant Chemist, New York Health Department. Since September, 1892, Bacteriologist, New York Health Department. 1898, traveling in the West.

BEHRMAN, GEORGE WILLIAM, C.E., ... 1893.

143 Rutledge Street, Brooklyn, N. Y.

November, 1893, to January, 1894, Transitman and Draughtsman, with the Raub Locomotive Works and Land Improvement Company.

BELLINGER, HIRAM PAULDING, C.E., ... 1887.
Solvay Process Company and 1902 W. Genesee Street, Syracuse, N. Y.

BENEDICT, WILLIAM DE LIESSELINE, E.M., . . 1874.
Bank of Commerce Building, 31 Nassau Street, New York City, and 282 Vanderbilt Avenue, Brooklyn, N. Y.

1878–80, Assistant Superintendent and Superintendent, Revere Concentrating Co., Utah. 1880–81, Assistant Superintendent, Germania Smelting & Refining Co., Utah. In 1882, opened an office in New York City, as Consulting Mining Engineer and Metallurgist, and have since been engaged in examining and reporting on Mines in the United States, Ontario, Quebec, British Columbia, Mexico and England.

BENOLIEL, SOL. D., E.E., ... 1896.
Adelphi College, Brooklyn, N. Y.

BENJAMIN, MARCUS, PH.B., A.M. (Lafayette 1888), 1878.
PH. D. (Univ. Nashville, 1889) (Life Member).
Editor U. S. National Museum, and 1710 N. Street, N. W., Washington, D. C.

1878–82, with E. B. Benjamin, dealer in Chemical Apparatus. 1882, Editor *American Pharmacist*. 1883, Editor *Weekly Drug News*. May, 1883, to June, 1885, Chemist, U. S. Laboratory, New York. 1884–86, Lecturer on Chemistry, N. Y. Woman's Medical College and Hospital for Women. 1885, Sanitary Engineer, N. Y. Board of Health. 1886–89, Editorial Staff, Appleton's *Cyclopædia of American Biography*. 1890, Editorial Staff, *Engineering and Mining Journal*. 1891–94, Editorial Staff in charge of Chemistry, *Standard Dictionary*. 1894–95, Editorial work for D. Appleton & Co. 1895, Editorial Staff, *Johnson's Universal Cyclopædia*, New York. 1895–96, at the Smithsonian Institution, and since April, 1896, Editor U. S. National Museum, Washington, D. C. At various times on editorial staff of *Scientific American*, 1883–89; *Independent Oil Journal*, 1886; and on technical subjects in *New York Daily News*, 1886–95; *New York Star*, 1890–91; and *Pharmaceutical Record*, 1991; also of *Appleton's Annual Cyclopædia* since 1883. Other work includes translations of Berthelot's lectures on "Explosive Materials" (New York, 1883); authorship of Druggist's Circular, Prize Essay on "Disinfectants," 1885; authorship of chapters on *Mineral Paints* in "Mineral Resources of the United States," for years 1884–86, and other non-technical works. Organized the Corresponding Chapter of Chemistry of the Agassiz Association in 1892, and its President till 1896. Life fellow of the London Chemical Society, and of the American Association for the Advancement of Science of which he was elected a Vice-President, 1898, presiding over the "section on Social and Economic Science;" Member of Society of Chemical Industry, London, and of American Chemical Society, Member of International Jury of Awards, World's Fair, Chicago, 1893. Member of Assay Commission in 1896. Member of Jury of Awards, Tennessee Centennial Exposition, Nashville, Tenn., 1897. Member of Jury of Awards Trans-Mississippi and International Exposition, Omaha, Neb., 1898.

BERRY, WILTON GUERNSEY, PH.B., ... 1886.

Secretary and Treasurer Asepta Chemical Co., 108 Fulton Street, and 170 W. 78th Street, New York City.

1886-89, Universities of Berlin and Heidelberg and General Chemical Research. 1889, to date, Assistant Chemist, New York Health Department. Health Department New York City. 1897, Sec. & Treas. Asepta Chemical Co., New York City.

BERRY, GEORGE, C.E., ... 1888.

Assistant Engineer Department of Street Improvements, 23d and 24th Wards, 177th Street and 3d Avenue, New York City, and 78 Morton Street, Brooklyn, N. Y.

BETTS, ROMEO T., C.E., ... 1890.

Wallabout Basin, and 863 Jefferson Avenue, Brooklyn, N. Y.

BIEN, JOSEPH RUDOLPH, E.M., ... 1887.

140 6th Avenue, and 321 West 57th Street, New York City, N. Y.

1887-88, Topographer, U. S. Geological Survey, Survey of Geyser Basins, Yellowstone National Park. 1888-90, Practice as Civil and Mining Engineer, firm of Vermeule & Bien, New York City. 1890-91, Practice as Civil and Topographical Engineer alone, New York City. At present, Secretary Julius Bien & Co., Lithographers, Engineers and Geographical Publishers.

BINION, JOSHUA, B.S., C.E., ... 1895.

Care of Mrs. Freed—232 Madison Street, New York City.

Summer of 1893, Volunteer Assistant, New York Speedway. 1895, Assistant Summer School of Surveying, Columbia University. October, 1895, to November, 1897, Rodman, Draughtsman and Transitman, C. R. R. of N. J. November, 1897, Topographical Draughtsman, Department of Highways, New York City.

BISHOP, R. R., E.E., ... 1897.

American Telephone and Telegraph Co., 15 Dey Street, and 311 West 54th Street, New York City.

August, 1897, to May, 1898, with Chas. L. Eidlitz, Electrical Engineer and Contractor at 1133 Broadway, New York City. May, 1898, to date, with American Telephone and Telegraph Co. in operating department at 18 Cortlandt Street, New York City. December 1, 1898, made Assistant Chief Operator at New York office of A. T. & T. Co.

BLACK, ADOLPH, C.E., ... 1894.

Columbia University, and 1428 Lexington Avenue, New York City.

Assistant Instructor, Summer School of Surveying, Summers, 1893-97, inclusive. Assistant in Civil Engineering, Columbia College, 1894-96. State Inspector, New York State Tenement House Commission, 1894. Tutor in Civil Engineering, 1896-98. Instructor in Mathematics and Mechanical Drawing, Y. M. C. A., 23d Street Branch, New York City, 1893-95. Sanitary Inspector, Department Public Parks, 1895. Architect for Department Public Works, New York City, 1896-97.

BLAKE, EDWIN MORTIMER, E.M., PH.D. (1893), . 1890.
Instructor in Mathematics, Purdue University, Lafayette, Ind., also 230 Washington Avenue, Brooklyn, N. Y.

BLEECKER, C. P., ... 1881.
Care of R. G. and J. S. Packard Dredging Co., East 28th Street and 66½ Trask Avenue, Bayonne, N. J.

BLOSSOM, FRANCIS, C.E., ... 1891.
Westinghouse, Church, Kerr & Co., 26 Cortlandt Street, New York City, and 440 Henry Street, Brooklyn, N. Y.
1891–92, Engineer with C. W. Hunt Co. 1892, Assistant Engineer Equity Gas Works Construction Company. 1893, as above.

BODELSEN, OSCAR, E.M., ... 1884.
Cons. Gas Co., Foot West 44th Street, New York City, and Pocantico Hills, N. Y.

BŒCKLIN, WERNER, JR., C.E., ... 1891.
108 Fulton Street, and 228 West 38th Street, New York City, N. Y.
January to May, 1893, ran level on preliminary (150 miles), H. & E. Extension, C. O. & S. W. Railway, in charge of all profiles and estimates under Chief Engineer. 1894, Inspector for Massachusetts Highway Commission on State Highway. Assistant Engineer in charge of erection of Stone Crushing Plant at Rock Hill, N. J., 1895. 1896, in Chief Engineer's Office Pa. Company, Pittsburg, Pa.

BŒRNER, EMILE C., JR., E.E., ... 1897.
The Solvay Process Co., and Hotel Jefferson, Syracuse, N. Y.
After graduation worked four months with Port Chester Bolt and Nut Company as Assistant Mechanical Engineer and Mechanical Draughtsman. At present an Assistant Engineer of Tests in Mechanical Engineering Department of Solvay Process Company, Syracuse, N. Y.

BOGERT, MARSTON T., PH.B., A.B., ... 1894.
Havemeyer Hall, Columbia University, New York City, and 259 Broadway, Flushing, Queens County, L. I., N. Y.
Awarded University Fellowship in Chemistry for 1895, but resigned to accept position of assistant in Organic Chemistry. Assistant in Organic Chemistry, Columbia University, 1894-97, and Tutor in same, July 1 to October 15, 1897. Instructor in same from October 15, 1897, to date. Librarian American Chemical Society, 1898-99.

BOOK, DWIGHT DANA, C.E., E.E. (1892), . . . 1890.
159 Washington Park, Brooklyn, N. Y.

BOOKMAN, S. (Associate), PH.D., M.A., ... 1891.
1 Madison Avenue, and 9 East 62d Street, New York City.
Associate in Physiological Chemistry, Pathological Institute, New York State Hospitals.

BOORÆM, ROBERT ELMER, E.M. (Life Member), . 1888.
2 East 15th Street, New York City.

1879, Assayer, general work in Leadville, Colorado. 1880–87, Assistant Superintendent, afterward manager, Evening Star Mining Co., Morning Star Consolidated Mining Co. and others at Leadville, Colorado, Lead-silver Mines. Also in charge Farwell Con. M. Co., Gold Mines at Independence, Colorado. 1887–90, General Manager Blue Bird Mining Co., Ltd., Butte, Montana, Operating 90-Stamp Mill, Dry Crushing, Chloridizing, Amalgamating Process. 1891, General Consulting Mining Engineer, and Consulting Director in Gold, Silver and Lead-Mining Companies, of which a specialty is made. Also Mine Operator and owner, Silver Mines at Aspen, Colorado, and Consulting Engineer.

BOYD, RICHARD CHARLES, PH.B., A.M. (1892), . 1891.
115 West 71st Street, New York City.

BRADLEY, STEPHEN ROWE, JR., PH.B., . . . 1890.
Orangeburg and Nyack, N. Y.

July, 1891, to 1894, Secretary and Treasurer Union Electric Co. January, 1894, Secretary and Treasurer, The Arlington Manufacturing Co., New York City.

BRASCHI, VICTOR MANUEL, PH.B., E.M., C.E., . 1881.
Apartado 830, City of Mexico, Mexico.

June, 1884, to October, 1884, Inspector of New York Tenement House Commission. October, 1884, to May, 1885, Interpreter and Secretary to Chilian Governor, Commissioner sent to visit and report on American Mining and Smelting. May, 1883, to October, 1885, employed by Rend Rock Powder Co. in Flood Rock Explosion Work. October, 1885, to January, 1889, Assistant Consulting Engineer and in charge of Foreign Business, Rand Drill Co. January, February, March, 1889, Reporting on Mines in Mexico for above Co., and for three years, from April, 1890, to April, 1893, engaged in introducing Rand Rock Drilling Machinery in Mexican Mines. In April, 1893, arranged to open a General Mining Machinery and Supply business, in the City of Mexico, in which I am at present engaged. Agent for Mexico for Fraser & Chalmers, Rand Drill Co., John S. Robeling & Sons and Repanno Chemical Co.

BREERTON, THOMAS J., A.B., 1879, C.E., . . 1883.
Engineer Cumberland Valley Railroad and 5th Avenue, Chambersburg, Pa.

1879, Rodman on Location of Redstone Br. P. R. R. 1880 and 1882 (Summers) on New York State Geodetic Survey of Adirondacks. 1883–85, Leveling P. R. R. Clearfield Co. Surveys and Construction. On Corps of Engr. M. of W. P. R. 1888–89, Assistant Supervisor P. R. R. 1890–92, Supervisor Tyrone Div., P. R. R. 1893, Engineer Cumberland Valley Railway.

BREWSTER, HENRY DRAPES (Associate), . . . 1883.
Care Brewster & Co., 49th Street and Broadway, New York City.

BRINLEY, JOHN ROWLETT, C.E., ... 1884.
Morristown, N. J.

1884–88, Department of Public Works, New York City. 1888 to date, Civil and Sanitary Engineer.

BRITTON, NATHANIEL LORD, E.M., PH.D., . . 1879.
63 East 49th Street, New York City.

Assistant of Geology, School of Mines, 1879–1887. Instructor in Botany, Columbia University, 1887–1890. Adjunct Professor of Botany, Columbia University, 1890–1891. Assistant Geological Survey of New Jersey, 1880–1887. Botanist, Geological Survey of New Jersey, 1881, 1890. Field Assistant, U. S. Geological Survey, 1882. Professor of Botany, 1891. Specialty—Systematic Botany. Director-in-Chief New York Botanic Garden.

BROWN, ROBERT GILMAN, E.M., ... 1889.
Standard Consolidated Mining Co., Bodie, Cal.

BUCK, VICTOR BUCHANAN, Met.E., ... 1898.
Parry Sound, Ontario, Canada.

BUCKLEY, CHARLES RAMSAY, A.B., A.M., E.M., . 1877.
29 Broadway, New York City.

BURDEN, HENRY 2d, A.B., PH.B., ... 1892.
Cazenovia, N. Y.

BURNS, ABRAHAM LINCOLN, E.M., ... 1887.
Erecting Engineer, Jabez Burns & Sons, 542 Greenwich Street, and 501 West 113th Street, New York City.

Since November, 1887, with Messrs. Jabez Burns & Sons (Millwrights and Machinists and Manufacturers of Patented Machines for Treating Coffee and Spices). July, 1880, 1897, Member of the firm Track, Burns & Co. Professional work has been general shop draughting and machine design, and arranging machines and power transmission in coffee establishments.

BURNS, ELMER Z., E.M., ... 1887.
Niagara Falls, N. Y.

1887–88, Engineer and Chemist for the Pittsburg and Lake Angeline Iron Co. 1889–90, Assistant Electrician for the United States Electric Light Company. 1890–91, Assistant Electrician for the Mather Electric Company. 1891–93, City Engineer of Niagara Falls and Consulting Engineer for the Lewiston and Youngstown R. R. Company, for the North Tonawanda Street Railroad Company, and for the Niagara Falls and Suspension Bridge Railroad Company.

BURNS, WM. G., E.E., ... 1898.
423 West 117th Street, New York City.

Since August, 1898, with New York Telephone Co.

BUTLER, NATHANIEL, E.M., ... 1880.
Glen Ridge, Essex Co., N. J.

1880–82, U. S. Harbor Improvement and Railroad Engineering. 1882–94, Barlow's Insurance Surveys as Surveyor, Superintendent and Executive.

BUTLER, WILLARD PARKER, E.M., LL.B. (Life Member), 1878.
Counsel in Patent Cases, 59 Wall Street, and 143 East 36th Street, New York City.

C.

CAIRNS, FRED. I., Met.E., ... 1890.
Supt. Bridgeport Copper Co., and 246 Park Avenue, Bridgeport, Conn.

1890-92, in charge of surveying party in Tennessee. 1892-93, Superintendent Mines, Ducktown, Tenn. 1893-97, Metallurgist Bridgeport Copper Co. 1897, to date, Superintendent Bridgeport Copper Co.

CALMAN, ALBERT, PH.B., PH.D., ... 1882.
7 West 75th Street, New York City.

CANFIELD, FREDERICK A., A.B., A.M., E.M., . . 1873.
Mining Engineer, Dover, N. J.

CARSON, JAMES PETIGRU, E.M., ... 1868.
Oakley, South Carolina.

CARTER, B. P., E.M., ... 1805.
Crown Deep Mine, Ltd., P. O. Box 771, Johannesburg, S. A. R.

December, 1896, to 1897, Surveyor and Assayer of the Crown Deep, Ltd. 1897, in charge of Surveying and Smelting.

CASAMAJOR, GEORGE H., C.E., ... 1892.
Asst. Editor *Cosmopolitan Magazine*, Irvington-on-Hudson, N. Y.

1892-May, 1893, with the *Railroad Gazette*, N. Y. May-September, 1893, with C. B. Brush, Hoboken, N. J., as Transitman, Levelman, etc. October, 1893-January, 1896, with the East River Gas Company, N. Y. February-May, 1896, Engineer Inspector D. P. W., N. Y. May, 1896, to January, 1898, a partner in the Bacheller Newspaper Syndicate, occupied in literary and editorial work. January, 1898, to date, Assistant Editor *Cosmopolitan Magaz ne.*

CASEY, EDWARD PEARCE, C.E., PH.B. (1888), . . 1886.
Architect, 171 Broadway and The Alpine, 55 West Thirty-third Street, New York City.

With McKim, Mead & White, Architects, New York City, until January, 1890. Abroad, and Student in L'Ecole National des Beaux Arts, Paris from February, 1890, until September, 1893. Five mentions in Architecture, and a medal in Modeling. At present Architecture, 171 Broadway, New York City. Architect for the completion of the Congressional Library Building Washington, D. C., from 1892 to 1897. Vice-President of the Blank Arts Society of Architects 1896, to date. Fellow of the American Institute of Architects in 1897.

CASWELL, KENNETH L., B.S., ... 1898.
114 East 31st Street, New York City.

CAULDWELL, JOHN BRITTON, C.E., ... 1877.
Century Club, 7 West Forty-third Street, New York City.

CHANNING, JOHN PARKE, E.M., ... 1883.
34 Park Place, New York City.

1893, Chemist Hudson River, O. and I. Co. 1884, with S. E. Cleaves & Son, Manufacturers of Mining Machinery, Houghton, Mich. 1884 95 Assistant Min-

ing Engineer Tamarack Mine, Calumet, Mich., Dep. Com. Mineral Statistics, Michigan. 1885–86, Superintendent Honduras Land and Navigation Co. 1886–87, Exploring for iron on the Gogebic Range, and Mining Engineer for Milwaukee, L. S. and Western Railway, Superintendent Iron Belt Mine. 1887–90, Inspector of Mines, Gogebic Co., Mich. 1890–92, Superintendent East New York Iron Co., Ishpeming, Mich. 1892–93, Superintendent Iron Exploration Co., C. M. and St. P. Railway. Assistant to General Manager Calumet and Hecla Mining Co., 1894, Consulting Work, 1894, to date.

CHESTER, ALBERT HUNTINGTON, A.M., E.M., SC.D., PH.D., 1868.
Professor of Chemistry and Mineralogy, Rutgers College, and 35 College Avenue, New Brunswick, N. J.

Professor of Chemistry at Hamilton College from 1870 and Mineralogy from 1878 to 1891. Conducted the Analytical Laboratory there from 1871. Chemist New York State Board of Health, 1882. Examined and reported on mines of iron, gold, silver, lead and zinc, in Michigan, Minnesota, Ontario, Arkansas, Colorado, Utah, Nevada, California and Nova Scotia. Analytical work has been largely in two lines, viz., for iron-blast furnaces and of paints and varnishes. Field work has been, a great part of it, in the iron mines of Minnesota and the gold mines of Colorado. Now engaged in chemical work for the State Geological Survey of New Jersey.

CHIBAS, LOUIS F., E.M., ... 1898.
Guantanamo, Cuba.

CHURCH, ELIHU DWIGHT, JR., E.M., ... 1887.
Secretary Church & Dwight Co., 63–65 Wall Street, New York, N. Y., and 116 Willoughby Avenue, Brooklyn, N. Y.

1887-88, Fellow Qualitative Analysis School of Mines. 1888–89, Assistant Superintendent of Lead Mine and Concentrating Works. 1889-91, with Church & Co., in charge of experiment plant. 1896, with Church & Co., Trenton, Mich.

CHURCH, JOHN ADAMS, A.M., E.M., PH.D., . . 1867.
Corn Exchange Building, 11 William Street, and 1350 Madison Avenue, New York City, Cable address Scotist, N. Y.

CLARK, ALLAN J., E.M., ... 1896.
Homestake Mining Co., Lead, S. D., and care of B. S. Clark, Box 1580, New York City.

1896 to May, 1897, Assistant Engineer T. C. I. & R. R. Co., Blocton, Ala. May, 1897, to date, Assayer Homestake Mining Co. and Associated Companies, Lead, South Dakota.

CLARK, CHAS. MARTIN, E.E., ... 1897.
Clark & MacMullen, Engineers 42 East 23d Street, New York City, and 171 Lefferts Place, Brooklyn, N. Y.

CLARK, DIEGO LOMBILLO, C.E., ... 1890.
Cardenas, Cuba.

CLARK, EDMUND (Associate), ... 1892.
Chemical Laboratory, Health Dept., Criminal Court Bldg., Centre and Franklin Streets, and 148 East 34th Street, New York City.

From August, 1892, to August, 1895, Assistant Chemist, Homestead Steel Works, Carnegie Steel Co., Pittsburg, Pa. Since August 1, 1895, Assistant Chemist, Health Department, New York City.

CLARK, EDWIN PERRY, E.M., ... 1880.

Title Guarantee and Trust Co., 175 Remsen Street, and 396 Fourth Street, Brooklyn, N. Y.

1880-83, Engineer and Surveyor for Silver-Cord Combination, and Robert E. Leo Mining Companies, Leadville, Colo. 1883-84, medical student. 1884 to date, Assistant Superintendent and afterwards Superintendent Title Guarantee and Trust Company, 55 Liberty Street, New York, and 26 Court Street, Brooklyn. In charge of construction and maintenance of locality-indexes of Real Estate Records of New York, Kings and Westchester counties, N. Y.

CLARK, GEORGE HALLETT, C.E., ... 1893.

The Monticello, 406 West End Avenue, New York City.

1893-94, Transitman Metropolitan Traction Co., Lexington Avenue Cable Construction. Assistant Engineer in charge construction Lexington Avenue Cable Road. Assistant Engineer D. D. I., from June 1, 1896, to date.

CLARK, JOSIAH HUNTOON, E.M., ... 1897.

228 Broadway, Paterson, N. J.

1897-98, with National Mexican Mining and Developing Co., as Engineer and Surveyor, located at El Plomo, Sonora, Mexico.

CLARK, WILLIAM C., M.E., ... 1892.

Sterling I. and Ry. Co., Sterlington, Rockland Co., N. Y.

COFFIN, TRISTRAM ROBERTS, ... 1898.

Roberts & Co., 31 Nassau Street, and 258 West 72d Street, New York City.

COKEFAIR, FRANCIS A., C.E., ... 1894.

66 Broadway, New York City, and 119 Crescent Avenue, Plainfield, N. J.

COLBY, ALBERT LADD, PH.B., ... 1881.

Metallurgical Engineer, the Bethlehem Iron Co., South Bethlehem, Pa.

1881-83, Assistant to Professor C. F. Chandler on New York State Board of Health Bureau of Chemical Analysts. 1883-89, Introduction in Quantitative Analysis and Chemical Philosophy in the Lehigh University, South Bethlehem, Pa. 1887-92, Head Chemist of the Bethlehem Iron Co. 1892, to date, Metallurgical Engineer same Company, South Bethlehem, Pa. Also July, 1897, Secretary and Treasurer Association of American Steel Manufacturers. Specialty, Metallurgy of Iron and Steel.

COLE, HAROLD MORRIS, E.M., C.E., . . . 1887.

Care United S. and R. Co., East Helena, and 1045 North Warren Street, Helena, Montana.

COLTON, CHARLES ADAMS, E.M., ... 1873.

367 High Street, and 57 Broad Street, Newark, N. J.

1873–82, Assistant in Mineralogy School of Mines, Columbia College, New York. 1882–84, Professor of Chemistry and Mineralogy, Rose Polytechnic Institute, Terre Haute, Indiana. 1884 to date, Director and Instructor in Chemistry and Physics, Newark Technical School.

CONANT, HENRY DUNNING, E.M., ... 1886.
Asst. Supt. the Lake Superior Smelting Co., Houghton, Mich.

1886–88, Assistant Engineer Tamarack and Osceola Mines, Lake Superior, and H. and C. R. R. 1888–89, Assistant Engineer on Preliminary of Northern Michigan Railroad. 1889, Assistant in Chief Engineer's Office, Buffalo and Geneva Railway. 1889–91, Assistant and Resident Engineer, Norfolk and Western Railroad, in charge of Preliminary Location and Construction. 1891, Engineer Coeburn Land and Improvement Co. 1893, Assistant Engineer, N. Y., N. H. & H. Ry. 1894, Assistant Engineer Playa de Oro Mining Co., Ecuador, S. A. 1895, Assistant Engineer Boston and Montana C. C. & S. M. Co. 1896–98, Manager Playa de Oro Mining Co., Playa Rica, Ecuador. 1898, Assistant Superintendent The Lake Superior Smelting Co., Mich.

CONGDON, ERNEST ARNOLD, PH.B., F.C.S., . . 1887.
Professor of Chemistry, Drexel Institute Arts, Science, and Industry, and University Club, Philadelphia, Pa.

1887–89, Chemist to Champlain Fibre Co., Willsborough, New York. 1889, Studied at the University of Berlin, Summer Semester. 1889 to date, Instructor in Qualitative Analysis and Assaying at the Lehigh University. 1891, Professor of Chemistry in the Drexel Institute of Arts, Sciences and Industries, Philadelphia, Pa.

CONOVER, JOHN T., E.E., ... 1898.
49 West 69th Street, New York City.

COOPER, WILLIAM HAMILTON, PH.B. (Life Member), . 1882.
Address unknown.

CORNWALL, HENRY BEDINGER, A.B., A.M., E.M., PH.D., 1867.
Professor Applied Chemistry and Mineralogy, Princeton University, and 51 Nassau Street, Princeton, N. J.

COX, JENNINGS STOCKTON, JR., MET.ENG., . . 1887.
General Manager Spanish Am. Iron Co., Santiago de Cuba, Island of Cuba, and 156 Meadow Street, New Rochelle, New York.

1887, Government Survey for Canal between Harlem and Hudson River. 1888–89, Homestead Steel Works, Draughtsman and afterward Assistant Master Mechanic. 1890, Inspected construction of Steamer "Sezurania" and "Vigilancia" for the U. S. and B. M. S. S. Co., at Roach's Shipyard, Chester, Pa. 1891, Reporter for same Company on Engineering matters along the Brazil coast. 1892, with same company in New York. 1892, Assistant Superintendent Aurora Iron-Mining Company, Ironwood, Michigan. 1893, Assistant Superintendent Monte Cristo Mining Co., Pride of the Mountain Mining Co., Rainy Mining Co., and United Concentration Company. 1894, Professional work in New York and Cuba. 1895, Agent Crocker-Wheeler Electric Co., Pittsburg, Pa.

COYKENDALL, EDWARD, C.E., ... 1895.
Roundout, N. Y.

COYKENDALL, FREDK., A.B., A.M., C.E., . . 1897.
Secretary Cornell Steamboat Company, Foot West 52d Street and 1 West 72d Street, New York, N. Y.

CRAMER, STUART W., E.M. (Associate), . . . 1889.
Manager The D. A. Tompkins Co., Charlotte, N. C.

Graduate of the United States Naval Academy; resigned from the United States Navy, September, 1888. Graduate Student at School of Mines, 1888–89. Assayer in charge of the United States Assay Office, Charlotte, N. C., 1888–93. Special agent for collection of statistics on gold and silver for the Southern states, 1890. March 10, 1893, to November, 1895, Manager for the D. A. Tompkins Company, General Engineers and Contractors, of Charlotte, N. C. November, 1895, to the present time Contractor and Dealer in Cotton Mill Machinery and Equipment. Specialty: Complete contracts for new cotton mills and the reorganization of old plants.

CRAMPTON, S. H., E.E., ... 1897.
32 Gold Street, New York City, and 95 Gates Avenue, Brooklyn, N. Y.

Edison Elec. Ill. Co., of New York. New York Telephone Co. Construction Department.

CROCKER, FRANCIS BACON, E.M., ... 1882.
Professor Electrical Engineering, Columbia University School of Mines (travelling on leave of absence during 1898–99), and 44 West 44th Street, New York City.

1882–86, Electrical Engineer and inventor. 1886–87, Vice-President and Electrician of "C. and C." Electric Motor Co. 1887-89, Vice-President and Electrician Crocker-Wheeler Electric Motor Co. 1889-92, Instructor in Electrical Engineering, School of Mines, Columbia University. 1892, Adj. Professor. 1893, Professor. Elected President American Institute Electrical Engineers, June, 1897.

CUSHMAN, ALEXANDER RAMSEY, PH.B., PH.D., . 1878.
128 East Sixteenth Street, New York City.

1878–80, Post Graduate study at the School of Mines, for degree of Ph.D. 1880–82, in Colorado, visiting mine and smelters. 1882–90, engaged in pursuing chemical studies and lecturing on geology. 1890 to July, 1897, Assistant Instructor in Qualitative Laboratory at the School of Mines, Columbia University.

D.

DALY, EDWIN HOWELL, E.E., ... 1898.
1064 Madison Avenue, New York City.

DARWIN, HARRY GILBERT, C.E., ... 1887.
Room 23, 160 Broadway, New York City, and Glen Ridge, N. Y.

June, 1887, to October, 1887, Rodman and Leveler on Railroad field work in New York State. October, 1887, to May, 1888, Draughtsman Strong Locomotive

Co., New York City. August, 1883, to date, Assistant Engineer and Acting Superintendent, Safety Car Heating and Lighting Co., New York City. Erection of special gas works, and equipment of railroad cars, etc. P. Asst. Eng. S. C. H. L. Co.

DAVIS, CHARLES HENRY, C.E., ... 1887.
Room 306 Fidelity and Casualty Building, 99 Cedar Street, New York City, and Upper Mount Clair, N. J.

Expert Course and Thompson-Houston Electric Co., Lynn, Mass., summer 1887. Agent Lawer Mann Electric Co., winter 1887-88. Supt. selling and construction New York office S. M. Elec Co., summer and winter 1888. Agent Westenhouse Electric Co., winter 1888. Consulting and Supervising Electrical Engineer from May, 1889, to date.

DAVIS, JOHN WOODBRIDGE, C.E., PH.D., . . . 1878.
523 West 173d Street, New York City.

DAVIDSON, WILLIAM STEWART, E.M., . . . 1897.
Manager Machinery Department, Clarkson & Co., Vladivostock, Eastern Siberia, Russia, via Japan.

1897-8, Representing Rand Drill Co. in China and Japan. July, 1898, to date, Manager Machinery Department of Clarkson & Co., Vladivostock, Eastern Siberia.

DEGHUÉE, JOSEPH ALBERT, PH.B., A.M. (1892), PH.D. (1893) . . . . . 1890.
Chemical Labaratory, Health Department, New York City, and 247 Harrison Street, Brooklyn, N. Y.

Assistant Demonstrator in Physics and Chemistry, College of Physics and Surgery, to March, 1896. March, 1896, to date, Assistant to Chemist, New York City Health Department.

DELFIELD, AUGUSTUS FLOYD, PH.D. (Associate), . .1869
University Club, New York City.

DELUZE, LOUIS PHILIPPE, C.E., ... 1879.
DeLuze & Emmett, Engineers and Surveyors, P. O. Building, New Rochelle, N. Y.

DENTON, FREDERICK WARNER, C.E., ... 1889.
Professor of Mining, School of Mines, University of Minnesota, and 1801 University Avenue, Minneapolis, Minn.

1889-90, Fellow in Engineering, School of Mines. 1890-94, Professor of Mining and Civil Engineering, Michigan Mining School, and in general practice of engineering. 1894-95, Mining Engineer Minnesota Iron Co. 1895 to date Professor of Mining, School of Mines, University of Minnesota. Secretary of the Lake Superior Mining Institute since its organization in 1893.

DERLETH, CHAS., JR., B.S., C.E., ... 1896.
Columbia University and 674 East 135th Street, New York City.

Assistant in Civil Engineering, 1896 to date. Assistant in Litchfield Survey-

ing School, 1896 and 1898. Assistant in Geodetic School, 1896, 1897, 1898. Summer 1897, Transitman on Rapid Transit Surveys. Instructor in Mechanical Drawing, Algebra and Geometry, Y. M. C. A., 23d St. Branch, 1896 to date.

DETWILLER, CHAS. HENRY, PH.B., ... 1885.

Detwiller & Melendy, Architects, 97 Nassau Street, New York City and 56 Danforth Avenue, Jersey City, N. J.

1885 to 1888, studying in architect's office in New York and traveling in Europe. 1888-92, Practicing Architect in Jersey City. 1892 to date, Practicing Architect in New York City.

DEVEREUX, WALTER BOURCHIER, A.B., A.M., E.M., . 1878.

Care of Ledoux & Co., 98 John Street, New York City and Glenwood Springs, Colo.

DOBBINS, MAX, E.M., ... 1895.

Care of Lehigh Valley Coal Co., Engineering Department and 14 Wright Street, Wilkesbarre, Pa.

DODGE, FRANK DESPARD, PH.B., PH.D. . . . . 1888.

Dodge & Olcott, 137 Water Street, and 111 Montague Street, Brooklyn, N. Y.

From October, 1891, to date, Chemist, with Dodge & Olcott, manufacturers of essential oils, etc. 1888-90, Fellow in Chemistry, Assistant in Organic Laboratory School of Mines. 1890-91, studying in Germany.

DOLAN, CHARLES FRANCIS, C.E., ... 1892.

Dept. of Public Works, 150 Nassau Street, and 111 East 129th Street, New York City.

1892-93, United States Inspector of Dredging Operations, Harlem Ship Canal and Newtown Creek. 1893, to date, with Department of Street Improvements, New York City. 1894, with U. S. Engineers on New York Harbor Improvements. 1895, Bridge Shop Practice and October, 1895, to date, with Department of Public Works, New York, N. Y.

DOUGLAS, JOHN SHEAFE, C.E., ... 1890.

Columbia Electrical Supply Co., 329 Fourth Avenue, and the Rockingham, 56th Street and Broadway, New York City.

1890, Course Electrical Engineering, Columbia College. 1891, Crocker-Wheeler Electric Motor Company. 1892, Assistant Engineer Western Electric Company in Lighting Department. 1893, Superintendent of Union Elect. Co.'s Exhibit at World's Columbian Exposition, Chicago. 1895, Secretary and Treasurer Chapin-Douglas Elec. Co. 1896, Columbia Electrical Supply Co., 329 Fourth Avenue, New York City.

DOUGLASS, EDWARD MOREHOUSE, C.E., ... 1881.

Togographer U. S. Geol. Survey, and Takoma Park, Washington, D. C.

1897, Geographer U. S. Geological Survey.

DOW, ALLAN WADE, PH.B. (Life Member), . . 1888.

Office of the Engineer Commission, District of Columbia, and 2016 Hillyer Place, Washington, D. C.

1888–89, Honorary Fellow Quant. Laboratory, School of Mines. 1889, Chemist at Tilly Foster Mine, New York. 1889–94, Assistant Chemist of The Barber Asphalt Paving Co. 1894, District Chemist, Inspector Asphalt Cement and Building Stones, District of Columbia.

DOWNS, WILLIAM FLETCHER, E.M., . . . 1882.

Joseph Dixon Crucible Co., and 75 Fairview Avenue, Jersey City, New Jersey.

With the Joseph Dixon Crucible Co., since graduation. From June, 1882, to September, 1882, at experiment work. From September, 1882, to October, 1884, in charge of lubricating department. From October, 1884, to present time, Superintendent of crucible and other departments.

DRASEL, CHARLES, E.M., ... 1895.

56 Bowers Street, Jersey City, N. J.

From October, 1896, to February, 1897, Mining Engineer and Surveyor. February, 1897, to January, 1898, Assistant Metallurgist and in charge of both blast furnaces and converting plants of the Mazapil Copper Co., of Concepcion del Oro Zacatecas, Mexico.

DRESSER, DANIEL LE ROY, C.E., ... 1889.

574 Broadway, New York City, and Oyster Bay, L. I., N. Y.

DRUMMOND, ISAAC WYMAN, E.M., PH.D., . . 1878.

F. W. Devoe & Co., William and Fulton Streets, New York City.

DUFOURCQ, EDWARD LEONCE, E.M., . . . 1892.

Olcott, Fearn & Peele, 18 Broadway, and 62 West 48th Street, New York City.

1892–93, Assistant Superintendent Costa Rica Pacific Gold Mining Company, Punta Arenas, Costa Rica. Summer of 1893, Assistant in Mining, Columbia College and Transitman for J. F. Carey & Co., Brooklyn. November, 1893, Assistant Engineer, Mazapil Copper Company, Concepcion del Oro, Zacatecas, Mexico, and Assistant Engineer Coahuila and Zacatecas Railroad. December, 1894, to November, 1896, Superintendent of International Mining Co., San Miguel del Mezquital, Mexico. November and December, 1896, Assistant Manager Mining Department, Cons. Kansas City Smelting and Refining Company, El Paso, Texas. January, 1897–98, Superintendent of Mines, same company, at Sierra Mojada, Mexico. 1898, to date, with firm Olcott, Fearn & Peele.

DUNHAM, EDWARD KELLOGG, PH.B., . . . 1881.

338 East Twenty-sixth Street, New York City.

Professor of Pathology, Bacteriology and Hygiene in the Bellevue Hospital Medical College, New York City.

DURHAM, H. W., C.E., ... 1895.

Care of Nicaragua Canal Commission, Greytown, Nicaragua.

Draughtsman Rapid Transit Commission, June to December, 1895. Field Assistant U. S. Geological Survey, May, 1896–97. 1897, to date, member of the permanent staff of Wm. Barclay Parsons, C.E., and now (Oct., 1898) temporarily engaged on surveys for the Nicaragua Canal by the Department of State.

DUSENBERRY, WALTER LORTON, M.E., ... 1884.

220 Tenth Street, South Brooklyn, N. Y.

1884–87, miscellaneous. U. S. Coast Survey. Mining in Mexico and the West. Survey of New Parks, Westchester County, etc. 1887–89, Inspector of Masonry and Transitman on New Croton Aqueduct. 1889–91, in charge of party and Assistant Engineer of Construction, Department of Public Parks, New York City.

DWIGHT, ARTHUR SMITH, E.M., ... 1885.

Cons. Kansas City Smelting and Refining Co., Argentine, Kansas.

1885, Assistant Assayer at works of The Colorado Smelting Company, Pueblo, Colorado. 1885–88, Assistant Chemist and Chemist, except autumn of 1886, when examining and reporting on lead deposits of Cœur d'Alene region, Idaho Territory, and spring of 1889, when acting as Assistant Superintendent Madonna Mine, Monarch, Colorado. 1889–90, Metallurgist, and up to date, General Superintendent of the Colorado Smelting Co. December, 1896, to date, General Superintendent Cons. K. C. Smelting and Refining Co., in charge of Operating Department of all plants of that company in United States and Mexico.

E.

EASTON, LANGDON CHEVES, C.E., ... 1884.

59 Flood Bldg., and 1906 Bush Street, San Francisco, Cal.

1885–88, Engineer Corps, Aqueduct Commission, New York City. 1889–96, Inspector and Assistant Engineer engaged in River and Harbor Improvement in California under direction of Corps of Engineers, U. S. A.

EASTWICK, GEORGE SPENCER, C.E., ... 1879.

Manager American Sugar Refining Co., 24 North Peters Street, New Orleans, La., and 1425 Broadway, New York City.

EBERHARDT, WILLIAM G., E.M., ... 1891.

450 West Twenty-second Street, New York City.

1891–93, General Engineering and Draughting. March, 1893, to May, 1894, Assistant Superintendent and Assayer Powhatan Land and Mining Co., Va. 1894–95, Assayer and Surveyor Mazapil Copper Co., Zacatecas, Mexico. 1896, Professional work in New York and New Jersey. April, 1897, to date, Assaying and ore testing, with Ricketts & Banks.

ECKERSON, CHAS. H., E.M., ... 1898.

Closter, Bergen Co., N. J.

University Scholarship in Geology for year 1898–99.

EDWARDS, RICHARD MASON, E.M., ... 1886.

Red Jacket and Houghton, Mich.

1886–87, General Assay office at Houghton, Mich. 1888–89, Professor of Mining, Michigan Mining School, Houghton. 1890, to date, Mining Engineer for Tamarack, Tamarack, Jr., Osceola and Kearsarge Mining Cos., L. S. Mich.

EILERS, KARL EMRICH, E.M., ... 1889.

Superintendent Colorado Smelting Co., Pueblo, Colo.

1889–91, student and traveling in Europe. 1895–96, Assistant Superintendent Colorado Smelting Co., Pueblo, Col. 1896, Kansas City S. & R. Co., El Paso, Texas. 1897, to date, Superintendent Colo. S. & R. Co., Pueblo, Colo.

ELLIOTT, ARTHUR HENRY, PH.B., PH.D., . . . 1881.
4 Irving Place, New York City, and New Rochelle, N. Y.
Professor Chemistry and Physics, New York College of Pharmacy. Chemist to Consolidated Gas Co. Editor Anthony's *Photographic Bulletin*. Author A. H. Elliott's Qualitative Chemical Analysis.

ELLIOTT, WILLIAM, PH.B., ... 1880.
56 Wall Street, New York City.

EMANUEL, L. V., C.E., ... 1897.
Asst. to Supt. Assayer and Cashier, Las Minas de Cobre de Tepezala, Tepezala, Aguascalientes, Mexico.

ENGEL, LOUIS GEORGE, E.M., ... 1880.
Brooklyn Sugar Refinery, American Sugar Refinery Co., Kent Avenue and South 2d Street, and *for mail* 142 Ross Street, Brooklyn, N. Y.
Three years, Tilly Foster Iron Mine (E. M.). Thirteen years, Brooklyn Sugar Refinery.

ENGELHARDT, EUGENE NICHOLAS, E.M., . . . 1885.
Selby, Contra Costa Co., Cal.
1886, Assayer, Chemist and Assistant Superintendent Pueblo Smelting and Refining Co. 1887 and 1888, Superintendent of the same company. 1889, Assistant Superintendent Anaconda Smelting Co. From 1890 and to present time, Assistant Superintendent Selby Smelting and Lead Co.

EVANS, I. N., C.E., ... 1895.
Evans, Almirall & Co., 623 John Hancock Bldg., Boston, Mass.

F.

FAHYS, GEORGE ERNEST, C.E., ... 1884.
38 Maiden Lane, New York City, and 285 DeKalb Avenue, Brooklyn, N. Y.
Treasurer Prentiss Calendar Time Co.

FEARN, PERCY LE ROY, E.M., ... 1889.
18 Broadway, N. Y.
1889-90, Assayer and Surveyor, Trinidad Mine, Costa Rica. 1890-92, Superintendent Trinidad Mine, Costa Rica. 1892-93, Consulting Mining Engineer, Illinois Fluor Spar and Lead Co. 1893-94, Vice-President of above. 1894-96, engaged in examining and reporting on Mines in Western States and Mexico. 1896, entered firm of Olcott, Fearn & Peele, 18 Broadway, New York.

FERGUSON, WILLIAM CUSHMAN AUGUSTINE, PH.B., . 1887.
Nichols Chemical Co., Laurel Hill Chemical Works, Laurel Hill, N. Y., and 40 North Parsons Avenue, Flushing, L. I., N. Y.
Chief Chemist Nichols Chemical Co., Laurel Hill, N. Y.

FERGUSON, GEORGE ALBERT, PH.B., ... 1890.
110-115 West 68th Street, New York City, and 303 Stuyvesant Avenue, Brooklyn, N. Y.

Professor of Analytical Chemistry and Mathematics, College of Pharmacy, City of New York. Inspector of Medical Supplies, Baking Powder, etc., for the Indian Bureau of the Interior Department.

FERRER, CARLOS FERRER, C.E., ... 1883.
39 Broad Street, New York City.

After graduation for a few weeks on work at the School of Mines. Then under Mr. W. E. Worthen, C.E., on some work for the Water Commissioners of the State of New Jersey. From March 1, 1884, to January, 1887, on the Engineering Corps of the Aqueduct Commissioners, New York City, as Assistant to Engineer of Construction; Leveler in charge of field work on Section "A;" reduced to Rodman in charge of same; promoted to Assistant Engineer; resigned in January, 1887, and have since been engaged in business for my own account at above address.

FERRIS, JUNIUS COLTON, E.M., ... 1883.
Carthage, Ills.

FEUCHTWANGER, HENRY, PH.B., ... 1882.
Room 19, 99 Franklin Street, New York City.

FIALLOS, ENRIQUE CONSTANTINO, C.E., ... 1883.
No. 27, Calle 10a, Tegucigalpa, Honduras, C. A., and Care Ernest Schernikow P. O. Box 3540, New York City.

General Practice in Engineering. Professor of Mathematics and Mineralogy in the University of Tegucigalpa. The most extensive practice has been as Government Surveyor of Lands and Mines.

FISHER, WILLARD, E.M. . . . . 1888.
Manager Sales Department Continental Match Co., 366 Washington Street, and 361 W. Fifty-sixth Street, New York City.

Draughtsman to W. B. Parsons, C.E., New York City. Assistant to Superintendent Segovia Gold Mining Co., Nicaragua. Clerk, Office of Rich Hill Coal Mining Co., Rich Hill, Mo. Engineer and Mine Surveyor, Rich Hill Coal Mining Co., Rich Hill, Mo. Prospecting for coal, Southwest Missouri, along the line of Wichlaw & Western in the interest of the Missouri Pacific Railroad. Southern Sales Agent, Coal Cos., on the lines of Missouri Pacific Railway. President Tyler S. E. Railway of Texas. 1897, Agent Illinois Zinc Co. 1898, Manager Sales Department Continental Match Co., and Eastern Sales Agent Illinois Zinc Co.

FOERSTER, DAVID, E.M., ... 1895.
5 East Pearl Street, Cincinnati, O.

Chemist, N. J. Zinc and Iron Co. Assayer and Surveyor, West Creek, Colo.

FOLGER, EDWARD P., ... 1894.
80 Quincy Street, Brooklyn, N. Y.

FOSTER, PELL W. (Associate), ... 1883.
Power Specialty Company, 126 Liberty Street, New York, N. Y.

FOSTER, REGINALD GUY, C.E., ... 1893.
16 East 31st Street, New York City.

FOWLER, SAMUEL STEWART, A.B., E.M., . . . 1884.
Drawer 505, Nelson, British Columbia, and Room 201, 36 Clark Street, Chicago, Ill.

1885, Civil Engineering Work, New York. 1886, Assistant Superintendent, Iron Hill Mining and Milling Co., Black Hills, South Dakota. 1897, Assistant Superintendent Galena Reduction Co., Black Hills, South Dakota. 1888, Superintendent, International Smelting Works, Texas. Engineer and Assayer, Bunker Hill and Sullivan Mg. and Cone Co., Idaho. 1889, Reporting sundry properties. 1890 to 1892, Superintendent Golden Mining and Smelting Co., Golden, B. C., Canada. Deputy Commissioner World's Columbian Exposition, 1893. 1894-95, Sundry Examinations in British Columbia. Engineer the London and British Columbia Goldfields, Whitewater Mines Ltd. and Ymir Gold Mines Ltd., Nelson, B. Col., 1896-97.

FOYÉ, ANDREW ERNEST, C.E., ... 1890.
11 Broadway, also Department of Highways, 150 Nassau Street, and 163 West 79th Street, New York City.

1890-92, Engineer's office, M. W. P. R. R. 1892-94, Tutor in Civil Engineering, School of Mines. 1894 to date, Instructor in the same. Contractors' Consulting Engineer Nyack Sewerage System, Chief Engineer Inter-State Contracting and Construction Co. Ch. Eng. Construction Sodi Water Co. Ch. Eng. Constructions, Macademizing roads, Borough of Sodi. July 1, 1898, Resigned Position of Instructor in Civil Engineering Columbia University, to give whole attention to private practice. August 15, 1898, Appointed Principal Assistant Engineer Dept. of Highways New York City in charge of Riverside Drive, Viaduct and other Improvements.

FRANK, JEROME WILLIAM, PH.B., ... 1888.
20 Broadway, New York City.

FREEDMAN, WILLIAM HORATIO, C.E., E.E., . . 1889.
Columbia University and 157 W. 119th Street, New York City.

Post-graduate in Elect. Engineering, 1889-91. John Tyndall Fellow, 1891-92. Assistant to Professor Munroe in Surveying, Summers of 1890-92. Assistant to Professor Rees in Geodesy, Summer of 1891. Tutor in Electrical Engineering, School of Mines, 1892-95. Tutor in Mechanics, Columbia University, 1895 to date. Teacher and Lecturer in University Extension work, 1894-97. Public Lecturer to Board of Education for three terms in 1895-96 and one term in 1896-97. Associate Editor of Electric Power, 1895-96. Member of Firm, Freedman, Rennard & Co., Electrical Engineers and Contractors February, 1884 to February, 1898. Member of Americal Mathematical Society and Full Member of American Institute of Electrical Engineers.

FRIEDMAN, SAMUEL, C.E., ... 1892.
Tuscaloosa, Ala.

FURMAN, HOWARD VAN FLEET, E.M., . . . 1881.
Room 118, Boston Building, Denver, Col.

1882-88, Assayer and Chemist and Foreman, Germania Lead Works, Utah, Chemist, Globe Smelting and Refining Co., Denver. Assistant Superintendent, Billings Smelter, Socorro, New Mexico. Superintendent, Bailey Smelter, Den-

ver, Colo. 1888 to 1894, Consulting Mining Engineer and Metallurgist, Office in Denver. 1894 and 1895, Chief Assayer U. S. Mint, Denver, Colo. 1896, Professor of Mining and Metallurgy, Colorado State School of Mines, Golden, Colo., also office as above.

G.

GARLICHS, HERMAN, E.M., ... 1880.

Care of Cons. K. C. S. & R. Co., Argentine, Kansas.

1880-83, Surveying and Reporting on Mines in Colorado. 1883-87, Assistant Superintendent, Aurora S. & R. Co., Aurora, Ill. 1887 to 1894, Superintendent Refining Department, Omaha and Grant S. and R. Co. Specialty, Silver and Lead Smelting and Refining. 1894, Metallurgist, Velardena Mining Co. Superintendent Refining Department. Cons. K. C. S. & R. Co. Oct. 1, 1895, to date. Superintendent Smelting and Refining Departments, 1897.

GILDERSLEEVE, ALGER C., C.E., ... 1895.

28 West 48th Street, and 39 Cortlandt Street, New York City.

1889 to 1892, Studied Law ; 1892, Laborer ; 1893, Transitman ; 1894, Assistant Engineer, Departments of Docks, New York City, resigned in June, 1894, to accept position as Engineer for John C. Rodgers, Contractor, on construction of the Second Section Harlem River Driveway. Resigned in November, 1895, and opened a private office at 39 Cortlandt St., as Engineer and Contractor for Piers, Docks, Foundations and Heavy Masonry.

GIFFORD, STANLEY DEVOL, E.M., ... 1889.

Treasurer, Montana Ore Purchasing Co., 100 Broadway, New York, and Butte, Montana, also 57 West 75th Street, New York City.

Treas. Montana Ore Purchasing Co., of Butte, Montana, Vice-President British Columbia Smelting and Refining Co., of Trail, B. C., and Vice-President of The Columbia and Western Railway Co., of Trail, B. C.

GILLETTE, HALBERT POWERS, ... 1892.

Assistant State Engineer, Powers Block, Rochester, N. Y.

1892-94, Deputy County Surveyor on Highways and bridges ; 1894-95, Boat Railway Survey, Dalles, Ore., contractor and designer for highway bridges ; 1894, Asst. Summer School of Surveying, School of Mines. Asst. Dept. Physics, 1895. Asst. to State Engineer, N. Y., on Canal Improvements. Assistant New York State Engineer since March 1, 1896.

GODLEY, RICHARD D., JR., E.E., ... 1896.

Department of Public Building, Lighting and Supplies, Jamaica, Borough of Queens and Whitestone Landing, Borough of Queens, N. Y.

October, 1896, joined the Brotherhood of Electrical Workers, Knights of Labor and did practical work as a journeyman wireman for one year with the different electrical equipment companies of New York City, chiefly with the Tucker Electrical Equipment Co., from October 1, 1897, to April 1, 1898. Superintendent New Jersey Electrical Equipment Co., from April 1, 1898, to the present, Consulting Engineer of Lighting and Electricity to the Department of Public Buildings, Lighting and Supplies, Borough of Queens, New York City.

GOING, CHARLES BUXTON, PH.B., ... 1882

Editor Engineering Magazine, 120–122 Liberty Street, New York City.

1882, Chemist to the Cincinnati Desiccating Co.; 1884, Porter & Gonig, Cincinnati, Ohio, expert and consulting practice; 1887–1896, Vice-President, General Manager and President of the Cincinnati Desiccating Co., Cincinnati, Ohio. 1892–96, Trustee, Secretary and Treasurer of the Glendale Water Works, Glendale, Ohio.

GOLDSCMIDT, SAMUEL ANTHONY, A.B., A.M., E.M., PH.D., (Life Member), ... 1871.

President Columbia Chemical Works, 43 Sedgwick Street, Brooklyn, N. Y., and New York City.

Assistant Ohio Geological Survey, 1871. Chemist and Assistant Inspector of Fertilizers, Savannah, Ga., during winters of 1871–75. During summers, Assistant to Dr. Chandler, Inspector New York Board of Health, 1873–75. Reporting on Guano Islands, South Pacific, 1876. General Consulting Practice, 1876–80. Inspector Offensive Trades, New York Board of Health, 1879–88. Treasurer Columbia Chemical Works, 1880–91. Specialty, Ammonia Manufacture.

GOOD, GEORGE MCCLELLAN HOUTZ, E.M., . . 1886.

Osceola Mills, Clearfield Co., Pa.

1887–91, Engineer to the Houtz Estate, Houtzdale, Pa. 1892, Mining Engineer to the United Collieries Company. 1892, Assistant General Manager of the same. Also in 1895, Assistant Engineer Altoona & Phillipsburg connecting R. R. July, 1895, Chief Engineer of same. August, 1897, General Superintendent A. & P. C-R. R.

GOODWIN, EDWARD, E.M., ... 1891.

Moscow, Idaho.

July, 1887–October, 1889, on Harlem River Canal, New York. 1891, Assistant in Mineralogy, and to spring of 1893, Assayer for Tombstone Mill and Mining Co., Tombstone, A. T. Spring of 1893, Experimental Cyanide plant at Tombstone, A. T. Fall of 1893–summer, 1894, Assayer at Texas Con. Gold Mine, and Assayer and Assistant Superintendent at Bully Choop Mines, Shasta Co., California. December, 1894–June, 1895, Assayer, Puget Sound Red Co., Everett, Wash. June, October, 1895, Assayer and foreman, Monto Cristo Mining Co., Monto Cristo, Wash. October, 1895, Prof. Mining, University of Idaho, Moscow, Idaho.

GORDON, JOHN, E.M., ... 1871.

Care of G. O. Gordon, 66–70 Beaver Street, New York City.

Merchant, Edward Johnson & Co., 62 San Pedro, Rio de Janeiro, Brazil.

GOSLING, EDGAR BONAPARTE, E.M., PH.D., . . 1884.

In Europe.

Tutor in Mathematics, Columbia University from 1884 to 1885. Draughtsman and afterwards Assistant Engineer in Departments of Docks, New York City, 1886–88. In Manufacturing Business In Paris, France, 1888–89. Tutoring in Mathematics and Engineering Branches in New York, and Superintending build-

ing of houses, introducing Culm-burning Furnaces in U. S., 1889-91. In charge of erection of buildings in artificial stone (Beton Coignet), for the Suez Canal Company, Egypt.

GOULD, EDWIN H. (Associate) (Life Member), . . 1888.
195 Broadway, New York City.

GRAFF, CHARLES EVERETT, E.M. . . . . 1885.
21 Garden Avenue, Jersey City, N. J.

1885-87, Assistant Engineer, Central Entre Riano Railroad, Argentine Republic, S. A. 1887-88, Engineer, Arizona Union Mining Co., Prescott, Arizona. 1888-90, Manufacturing Work, Binding Twine and Reapers. 1890-91, Engineer, Eagle Oil Co.

GRANGER, A. D., C.E., ... 1892.
Burhorn & Granger, 95-97 Liberty Street, New York City, and 677 Greene Avenue, Brooklyn, N. Y.

Summer and Fall, 1892, with C. W. Hunt Co., and E. P. Gleason Mfg. Co., a draughtsman. November, 1892-November, 1893, draughtsman, Link Belt Engineering Co., New York branch. Member of firm of Burhorn & Granger from November, 1893, to date. Specialties: Boilers, Engines, Complete Steam and Electric Plants.

GRATACAP, LOUIS POPE, PH.B., ... 1876.
Curator American Museum Natural History, Seventy-seventh Street and Eighth Avenue, New York City, and West New Brighton (Richmond County), Staten Island, N. Y.

GREENLEAF, JAMES LEAL, C.E., ... 1880.
Consulting Engineer, No. 1 Broadway, New York City, and Somerville, N. J.

Special Agent for Tenth Census for Water-power from 1880 to 1882. Since instructing in engineering, civil and sanitary, in School of Mines, Columbia University. 1891, Adjunct Professor Civil Engineering, Columbia University.. Resigned professorship in 1895 and gave exclusive attention to business as Consulting Engineer.

GREENE, DAVID JOY, C.E., M.E. (Sibley College) . 1894.
Supt. Jordan Works, American Cement Co., Jordan, N. Y.

June, 1895, graduated from Sibley College, Cornell University, with degree of Mechanical Engineer. August, 1895, to 1898, Superintendent of the Standard Silica Cement Co., Long Island City, N. Y. 1898, Superintendent Jordan Works, Am. Cement Co., Jordan, N. Y.

GROSS, LOUIS NATHAN, B.S., E.M., ... 1884.
Merchant and 38 East Fifty-eighth Street, New York City.

GUDEMAN, EDWARD, PH.B., PH.D., ... 1887.
The Glucose Sugar Refining Co., Chicago, Ill., and Box 3001 New York City.

Student at Berlin and Göttingen, 1887-1889. Honorary Assistant at the S. of M. and Private Assistant to Professor C. F. Chandler, 1889-90, Professor of Chem-

istry, in charge of the Department of Chemistry, Dyeing and Pottery at the Pennsylvania Museum and School of Industrial Art, Philadelphia, Pa., 1890-91. Chemist with the American Glucose Co., at Buffalo, N. Y. and Peoria, Ill., 1891-92. Chemist and Superintendent of the Peoria Grape Sugar Co., 1892-1895. Superintendent Davenport Syrup Refining Co., Davenport, Ia., 1895-97. Superintendent The Glucose Sugar Refining Co., Chicago, Ill., 1897 to date.

GUDEWILL, CHARLES EDWARD, C.E., ... 1890.
Montreal Pipe Foundry Ltd., P. O. Box 739 and 18 St. Matthew Street, Montreal, Canada.

1890-91, Assistant in Engineering Department, School of Mines, under Professor Trowbridge. 1891-96, Assistant Engineer Dominion Construction Co., Montreal, Canada. In charge of all pipe laying for Montreal Water and Power Co. Engineer of reservoir built by the company, capacity 7,000,000 gallons. Superintendent crossing of Lactine Canal with lines of 14-inch flexible pipes. January 1, 1897, appointed Engineer of Montreal Pipe Foundry Co., elected Vice-President April, 1897. Made Survey of Lac à la Fortue, Canada, for the Canada Iron Furnace Co., in June, 1897, and located ore deposits in lake. September 1, 1897. elected Associate Member American Society of Civil Engineers.

GUITERMAN, EDWARD WOLF, PH.B., ... 1889.
Passaic Print Works, Passaic, N. J.

1890-96, Chemist Passaic Print Works, Passaic, N. J.

H.

HAAS, EDWARD F., C.E., ... 1894.
320 Sansome Street, San Francisco, Cal.

HAASIS, DUNBAR FERDINAND, E.M., ... 1883.
U. S. S. "Gedney," and 59 Rector Street, Perth Amboy, N. J.

1883-84, Inspector of bridge work, Stony Point, N. Y. 1885-88, Assayer and Chemist, afterwards General Manager Parral Mining and Milling Co. (silver), Mexico, 1889, with Corps of Engineers, U.S.A., on New York Harbor Improvements. 1890 to date, Engineer Marion Phosphate Co., Florida, and Engineer Hamburgh Phosphate Co., Florida, surveying, prospecting and reporting on Phosphate deposits. 1892-93, with U. S. Engineers in charge construction Concrete Fortifications. In charge of Harbor Improvements. Assistant Engineer Dominion Construction Company for pipe laying and Reservoir engineering.

HADDEN, HOWARD S., B.S., PH.B., ... 1895.
106-108 Beekman Street, New York City, and 136 Willow Street, Brooklyn, N. Y.

HAFFEN, LOUIS FRANCIS, A.M., C.E., . . . 1879.
President of the Borough of Bronx, New York City, Municipal Bldg., Crotona Park, and 647 Cortlandt Avenue, 23d Ward, New York City.

HALE, ALBERT WARD, A.B., A.M., E.M., . . . 1867
Room 406, 32 Nassau Street, and 115 West 106th Street, New York City.

HALL, ROBERT WILLIAM, E.M., ... 1876.
Chemical Building, University of New York, University Heights, 24th Ward, New York City.

From 1879 to 1888, Chemist to the American Gas, Fuel and Light Company and to some associated companies. Since the autumn of 1888, Acting Assistant Professor of General Chemistry in the University of the City of New York. Since the autumn of 1890, also Acting Professor of Analytical Chemistry in the same institution. 1891, Professor of Analytical Chemistry, same instituion.

HALLOCK, ALBERT PETER, PH.B., PH.D., . . . 1880.
440 First Avenue, New York City, and 161 Sidney Avenue, Mt. Vernon, N. Y.

June, 1880, to October, 1880, with Dr. de P. Ricketts. October, 1880, to November, 1887, Chemist Consolidated Gas Co. November, 1887, to January, 1889, in the shell lime business. January, 1889, to date, Chemist to Carl H. Shultz, Mineral Water Factory. Specialty, Gas and Mineral Water Chemistry.

HAMILTON, FRANK C., E.M., A.M., ... 1894.
General Manager The Gold Creek Nevada Mining Company, Gold Creek, Nevada.

1894, Assistant Assayer Colorado Smelting Co., Pueblo, Colorado. 1895-98, Assayer Brodie Gold Red. Co., Cripple Creek, Colorado. 1898 to date, General Manager The Gold Creek Mining Co., Gold Creek, Nevada.

HANKINSON, ALBERT WORTHINGTON, C.E., . . 1893.
114 West Forty-fifth Street, New York City.

HANNA, GEORGE BYRON, A.B., E.M., . . . 1868.
Assistant Assayer United States Assay Office, Box 56, Charlotte, North Carolina.

Chemist and Assistant Geologist, North Carolina Geological Survey. Melter and Assistant Assayer U. S. Assay Office, Charlotte, N. C. Also, Consulting Mining Engineer and Chemist, etc.

HANSON, RICHARD COCHRAN, C.E., ... 1894.
74 West 91st Street, New York City.

HARDING, GEORGE EDWARD (Associate), . . . 1867.
Architect and Civil Engineer, 253 Broadway, New York City, and Mayhurst, New Brighton, Staten Island, N. Y.

Fellow American Institute Architect and Member American Society Civil Engineers.

HARRINGTON, THOMAS HENRY, C.E., . . . 1889.
Westchester, Westchester County, N. Y.

July, 1889, to March, 1893, Inspector Clerk and General Superintendent on U. S. Works, Flood Rock, Hell Gate, East River, N. Y. April to November, 1893, in charge of Exhibit of River and Harbor Improvements from New York City and Hudson River, at World's Columbian Exposition, Chicago. 1894-98, Assistant in Department Mechanical Engineering School of Mines, Columbia University.

HARRIS, EDWIN A., PH.B., ... 1889.
Chemist and Manager, The Mamilith Co., and The Arbor-ol-Chemical Co., Poplar Bluff, Mo., and 1294 Columbus Avenue, New York City.

1889-90, Chemist of the Camden Consolidated Oil Company. 1890 to date, Chemist Camden Consolidated Oil Company and agent for oil, mineral and timber lands in West Virginia and Ohio. Chemist to the Phosphorus Works of J. J. Allen's Sons, 2 Chestnut street, Philadelphia, 1892-93. April, 1893, to date, Secretary and Treasurer Globe Steam Heating Company.

HARTE, CHARLES R., C.E., ... 1893.
Office of Assistant Engineer of Construction, N. Y., N. H. & H. R. R., 269 Columbus Avenue, Boston, Mass., and 286 Chestnut Avenue, Jamaica Plain, Boston, Mass.

Engineering Department, N. Y., N. H. & H. R. R. on four-track elimination of grade crossings at Milfred, Conn., 1893-94, and at Boston, Mass., 1894 to date.

HASKELL, G. M., E.E., ... 1898.
225 West 28th Street, New York City, and 27 Morris Place, Bloomfield, N. J.

HASKELL, HARRY GARNER, E.M., ... 1893.
Secretary Repauno Chemical Co., and Hercules Powder Co., Wilmington, Del.

HATHAWAY, NATHANIEL, PH.B., ... 1879.
Swain Free School, and 43 Elm Street, New Bedford, Mass.

1879-80, Booth and Edgar Sugar Refinery. 1880-83, Private Assistant to Dr. E. Waller, New York. 1883-91, Teacher of Chemistry and Physics, Swain Free School, New Bedford, Mass., and general analytical work.

HAWLEY, JOHN FRANCIS, C.E. (Life Member), . . 1891.
Finca "El Tambor," San Filipe, Guatemala, Central America.

HÉBERT, OCTAVE BRITTON, C.E., ... 1888.
Empire Bldg., 71 Broadway, and 72 West 69th Street, New York City.

HEINSHEIMER, ALFRED MAURICE, C.E., ... 1887.
133 West 42d Street, and 17 West 70th Street, New York City.

October, 1897, entered firm of Traidel Bros. & Co., tile, marble and mosaic work, mantels, etc.

HENDRICKS, HENRY HARMON, P.B. (Life Member), . 1880.
Hendricks Bros., 49 Cliff Street, New York City.

HERZIG, C. S., E.M., ... 1895.
Asst. Supt. La Gran Fundicion Nac'l Mex'a, Sierra Mojada, Coahuila, Mexico, and 33-35 West Houston Street, New York City.

1895-96, Anaconda Copper Mining Co., Anaconda and Butte, Montana. 1896-97, Boston and Montana C. C. & S. Mining Co., Great Falls and Little Rocky

Mountains, Montana. 1897, professional work in Montana, South America, South Carolina and New York. December, 1897, to date, with La Gran Fundicion Nacional, Mexicana.

HEWLETT, JAMES MONROE, PH.B., ... 1890.

Lord & Hewlett, Architects, 16 East Twenty-third Street, New York City, and 154 Hicks Street, Brooklyn, N. Y.

1893, with McKim, Mead & Co., New York City. 1894, formed partnership with A. W. Lord as architects.

HILDBURGH, WALTER LEO, E.E., A.M., . . 1897.

1 West 30th Street, New York City, N. Y.

1898, Post-Graduate Study School of Applied Science, taking degree of A.M.

HILDRETH, WALTER EDWARDS, C.E., E.M., . . 1877.

Room 76, 115 Broadway, New York City.

HILL, WILLIAM, C.E., ... 1882.

Agent Collins Company, Box 196, Collinsville, Conn.

One year practical experience in manufacture of crucible steel. Two years draughtsman and Assistant to Master Mechanic of company manufacturing crucible steel, bar-iron, edge tools, plows and wrenches. Engineer in charge of Reconstruction of a dam 600 feet long, 32 feet high, at Otis, Mass. 1886-91, Assistant Superintendent for the Collins Company, manufacturing principally edge tools. November 1, 1891, appointed Agent of the Collins Company, with general change of plant at Collinsville, Conn., employing about 650 men, which position he still holds.

HINMAN, BERTRAND CHASE, PH.B., A.M. (1892), . 1890.

9–11 Worship Street, London, E. C., England.

From June, 1890, to August, 1891, Chemist to the Iron Clad Manufacturing Co., of Brooklyn, N. Y., improving the manufacture of sheet-iron enamelled ware. August, 1891, to June, 1895, Consulting Chemist for same Company. August, 1891, to March, 1893, Private Assistant to Professor Waller at the School of Mines. March, 1893, to end of the year, Manager of the Amorphous White Lead Co., of Brooklyn, N. Y., also a Director and subsequently President of this company. 1894, was devoted to experimental research on the improvement of methods for treating refractory gold ores. June, 1895, to end of 1896, Manager and Director of the "Nellie Bly Gold Mining and Reduction Co.," of Boulder, Colo., engaged in exploiting the "Cassel-Hinman Bromine Process" for refractory gold ores. Since 1896, Manager of the "Gold Extraction and Bromine Recovery Co., Ltd.," of London, England, exploiting the Cassel-Hinman Process.

HOLBROOK, FRANCIS NEWBERRY, C.E., . . . 1876.

Box 395, Tarrytown, N. Y.

From fall, 1876, to spring, 1880, Assistant Assay Laboratory School of Mines. Spring and summer on Geological Survey, West Texas. Then to 1884, spring, Superintendent Corralitos, Co., Chihuahua, Mexico. 1884-87, expert work, office, El Paso, Texas. Summer and fall, 1887, Superintendent of United Verde Copper Company, Arizona. 1888, spring, on geological work for the Southern Pacific Company in West Texas. Summer and Fall, running gold mine and Mill for self in Arizona. 1889-90, Manager for U. S. Circuit Court in suit between the

Con. Kansas City Smelting and Refining Company and the Guadalupe Company, in Nuevo Leon, Mexico. 1890 to February, 1891, employed by the Compañia Métalurgica Mexicana. March and April, 1891, charge of Copper Smelter, Tucson, Arizona. Expert work until 1892, when returned to Comp. Metal, Mexico. Still employed by the Compañia Métalurgica Mexicana and the Mexican Northern Railway Co.

HOLDEN, EDWIN C., B.S., E.M., ... 1896.
Box 505 Nelson, British Columbia, and 17 West 132d Street, New York City.

1896, Assistant Summer School of Surveying; Assistant in Mining Department 1896-97. 1897, Assistant in Analytical Chemistry, Columbia University. December, 1897, to date, Assistant Engineer, London and British Columbia Goldfields, Ltd.

HOLDEN, EDWARD HENRY, C.E., ... 1878.
1074 Boston Avenue, New York City.

HOLLERITH, HERMAN, E.M., PH.D. (1890), . . 1879.
Electrician and Expert, 1054 Thirty-first Street, Washington, D. C.

HOLLICK, ARTHUR, PH.B., PH.D., ... 1879.
Geological Department, Columbia University, New York City, and New Brighton, N. Y.

Superintendent Mexican Mine, Mariposa, Cal., 1880. New York City Health Department Inspector from 1881-90. Sanitary Engineer from 1890-91. Special Inspector, 1892. Special Expert and Inspector of Offensive Trades, New York State Board of Health, both in consultation and field work, from 1883 to date. Board of Health, Village of New Brighton, 1886-92, a member of the Board. Board of Health, Long Island City, Sanitary Adviser, 1890. In general practice as a sanitarian from 1883 to date. U. S. Geological Survey—engaged in collecting specimens in the Territories, in 1882. Appointed Fellow in Geology Columbia College, January, 1890; reappointed, 1891; Assistant, 1892. 1893, Tutor in Geology. Recording Secretary, Torrey Botanical Club, N. Y., 1883-88. Secretary, Natural Science Association of Staten Island, 1881 to date. Associate Editor *Bulletin*, Torrey Botanical Club, 1888 to date. Librarian New York Academy of Sciences, 1894 to date. Treasurer, Botanical Society of America, 1896 to date. Commissioner and President, Port Richmond (Staten Island) Boulevard Commission, 1896. Commissioner and Vice-President, Richmond County (Staten Island) Park Commission, 1897. Secretary, Section E, American Association for the Advancement of Science, 1898-99.

HOLLIS, HENRY LEONARD, E.M., ... 1885.
Mining and Metallurgical Engineer, 1161 The Rookery, Chicago, Ill.

HOLLIS, WILLIAM. C.E., ... 1878.
Box 133 Eagle Pass, Texas, Great Sales Agent for Alamo, Fuente and Coahuila Coal Companies.

HOLT, MARMADUKE BURRELL, E.M., ... 1889.

Silverton, Colo., and 287 Lexington Avenue, New York City.

1889-90, student in course of Electrical Engineering, School of Mines. 1890-91, with Aspen Mining and Smelting Company, serving as Mining and Electrical Engineer. 1891 to fall of 1892, Agent and Electrical Engineer with the "C. and C." Electric Motor Co., New York City and Denver. 1892-93, Assayer Colorado Smelting Co., Pueblo, Colo.

HOOPER, FRANK CYRUS, MET.ENG., ... 1890.

North River Garnet Co., North River, Warren Co., N. Y.

1890-91, Assistant Engineer De Lemar Mining Co., Limited. 1892-93, American Graphite Co. Spring, 1893, Investigation and report on Sisal Hemp Industry in The Bahamas for The Inauga Fibre Co. Summer and Fall, Erection of Concentrating Plants in Adirondacks. Superintendent North River Garnet Co., from 1893 to date. 1897-98, Assistant in Mining School of Mines.

HOPKE, THEODORE M., PH.B., ... 1880.

Monongahela Furnace Co., and 1107 South Park Street, McKeesport, Pa.

August, 1880, November, 1881, Analytical Chemist with Ledoux & Co., New York. November, 1881, to November, 1885, Member of the firm of Elliott Hopke & Mattison, Analytical and Consulting Chemists and Assayers. July, 1886, to November, 1889, Chemist for London Steel Co , of Pittsburgh, Pa., also had charge of physical testing department. November, 1889-1894, Manager Open-Hearth department of above company, having full charge of manufacture of all grades of steel made by the company, also building of open-hearth furnaces. 1894, Secretary and Assistant to General Manager, McKeesport Supply Company. 1897, Superitendent O. H. Dep't., Apollo Iron and Steel Co., Apollo, Pa. 1898, Monongahela Furnace Co., McKeesport, Pa.

HORNE, WILLIAM DODGE, PH.B., PH.D. (1894), . 1886.

Yonkers, N. Y.

June, 1886, to December, 1887, Chemist to Fulton Sugar Refinery, Brooklyn, N. Y. October, 1887, to December, 1887, Assistant Instructor in Chemistry, School of Mines, Columbia University. December, 1887, to June, 1888, Chemist to St. Louis Sugar Refinery, St. Louis, Mo. October, 1888, to October, 1889, Chemist to Standard Sugar Refinery, Boston, Mass. November, 1889, to present time General Analytical and Consulting Chemist. January, 1890, to January, 1893, Consulting Chemist to Delaware Sugar House, Philadelphia. January to June, 1891, Instructor in Analytical Chemistry in Rutgers College, New Brunswick, N. J. May, 1893, to present time, Consulting Chemist to National Sugar Refining Co., Yonkers, N. Y. Laboratory and office in New Brunswick from November, 1889, to September, 1893. From September, 1893, to present time in Yonkers, New York. In June, 1894, received from Columbia College the degree of Ph.D. in the Department of Chemistry and of Mechanical Engineering

HOWE, EPENETUS, E.M. (Life Member), . . . 1886.

Box 68 Monterey, Mexico, and North Salem, Westchester County, N. Y.

Assayer and Chemist with the El Paso Smelting Co , and the Argentine Works. Kansas, 1887-1889, and with Lucia Constancia Esmeralda Sierra Mojada Coahuila,

Mexico, 1889. Assayer, Chemist and then Superintendent, 1889–1895. May, 1895, to date, engaged in irrigation, mining and other engineering work for self on contract. 1897, General Assay and Mining Business and Consulting Engineer. Since summer of 1897 Engineering and Assay office of How & Norton, Monterey, Mexico.

HUNT, FREDERICK FURNEAUX, E.M., C.E., . . . 1876.
77 Pine Street, New York City, and 41 St. Marks Place, New Brighton, S. I., N. Y.

HUNTOON, L. D., E.M., PH.G., ... 1895.
Care Ducktown Sulphur, Copper and Iron Co., Ltd., Isabella, Tenn., and Paterson, N. J.

August to November, 1895, Assistant Chemist Phila. Smelting and Refining Co., Pueblo, Colo. December, 1895, to date, Assayer American Reduction Co, (Cyanide Mill), Florence, Colo. Fall of 1896 with Ricketts & Banks, New York City, making Metallurgical tests. 1898, Superintendent of Mines Ducktown Sulphur, Copper & Iron Co., Ducktown, Tenn.

HUTTON, FREDERICK REMSEN, A.B., A.M., E.M., C.E., PH.D. (Life Member), ... 1876.
Professor Mechanical Engineering, Columbia University, and 319 West 107th Street, New York City.

1876–77, Assistant in Engineering, School of Mines. 1877–82, Instructor in Mechanical Engineering. 1882–91, Adjunct Professor Mechanical Engineering. 1891 to date, Professor Mechanical Engineering, Columbia University. Secretary Alumni Association School of Mines, 1883 to date. Secretary American Society Mechanical Engineers, 1882 to date.

HYDE, FREDERICK S., PH.B. . . . . 1893.
Havemeyer Hall, Columbia University, New York City, and 215 Schermerhorn Street, Brooklyn, N. Y.

1893–94, Investigations in Glass for L. C. Tiffany, New York City. Assistant Chemist Brooklyn Department of Health, May, 1894–98. 1898, to date, Assistant to Professor Ricketts in Analytical Chemistry, Columbia University.

HYDE, HENRY ST. JOHN, PH.B., A.M. (1898). . . 1896.
210 East 18th Street, New York City.

1897–98, Post Graduate Student, Columbia University ; Candidate for A.M. in School of Pure Science. 1898–99, Candidate for Ph.D. in School of Pure Science, Columbia University.

I.

IHLSENG, AXEL OLAF, B.S., E.M., C.E., ... 1877.
Carthage, Mo.

1877–82, Chief Chemist, Havemeyer Sugar Refining Co., Brooklyn, E. D. 1882–90, U. S. Dep. Mining Surveyor, District of Colorado. 1882–83, Chemist and Assayer, La Plata Smelter, Leadville, Colo. 1883, Metallurgist, Martha Rose Smelter, Silverton, Colo. 1884, Assayer, Stoiber Sampling Works, Silverton, Colo. 1885, Duyckinck, Schuyler & Ihlseng, Ore Samplers, Silverton, Colo.

1886–90, Manager of Mt. Queen Mining Co., Reliance Mining Co., Brown Mining Co., and the Hale Mines, Silverton, Colo. 1890–92, Operating Zincite Mine and others near Webb City, Mo., and in constructing concentrating plants. Manager Pleasant Valley Mines, Carthage, Mo.

ILES, MALVERN WELLS, PH.B., PH.D. (Life Member), . 1875.
Superintendent Globe Smelting Co., Denver, Colo.

1875–76, Assistant to Dr. Waller in the Qualitative Laboratory, School of Mines. 1876–78, Chemical Fellow, Johns Hopkins University. 1878–79 Assayer and Chemist, in Colorado. 1879–80, Assayer at the Smelting Works of J. B. Grant, Leadville, Colo. 1880–83, Chemist of the Grant Smelting Co., Leadville, Colo. 1883–86, Metallurgist, The Omaha & Grant, S. & R. Co., Denver, Colo. 1886–87, Metallurgist, The Holden Smelting Co., afterwards changed to the Globe S. & R. Co. 1887–95, in present position. Contributed articles upon Assaying, various new Chemical methods, Mineralogy and Metallurgy in various publications.

INGERSOLL, WILLIAM HALSEY, A.B., A.M., LL.B., E.M., (Life Member), ... 1870.
Northport, N. Y.

1875–78, Assistant in Engineering, Columbia University. 1878–81, Assistant in Mechanics and Astronomy. 1881–87, Manufacturing tinware, Portland, Conn. 1887, to date, retired on account of ill health.

INGRAM, EDWARD LOVERING. C.E., ... 1885.
1106 Main Street, Buffalo, N. Y.

1885–86, U. S. Inspector of River and Harbor Improvements, Delaware. 1887–89, U. S. Surveyor and Inspector, River and Harbor Improvements, New York and New Jersey. 1890–91, U. S. Assistant Engineer, River and Harbor Improvements, Florida. 1891–94, Principal Assistant Engineer, International Boundary Survey, United States and Mexico. 1895 to date, Consulting Engineer.

J.

JACKSON, OSWALD, C.E., ... 1892.
150 Nassau Street, and 550 Park Avenue, New York City.

1892–93, Officers of Engineering M. W., U. R. R's. of N. J. Div., P. R. R. 1893, Engineer on Corps of Principal Assistant Engineer, U. R. R's of N. J. Div., P. R. R. 1895, Assistant Engineer, the New York Steam Company. 1896, Engineeer Inspector Department Public Works, New York City.

JACOBS, DAVID MARK, PH.B., ... 1887.
R. J. Jacobs, 41 New Street, and 30 West Thirty-eighth Street, New York City.

JACOBS, SOLOMON JOSEPH, PH.B., ... 1887.
R. J. Jacobs, 41 New Street, and 30 West Thirty-eighth Street, New York City.

JANEWAY, JOHN HOWELL, E.M., ... 1886.
John A. Roebling's Sons Co., and 124 West State Street, Trenton, N. J.

1886, Underground and Surface Surveyor for Cooper, Hewitt & Co. 1887-91, Draughtsman and Designer and Constructing Engineer of Wire Rope Tramways in Montana, Oregon, Alaska and California for the Trenton Iron Company, Trenton, N. J.

JENKS, ARTHUR WILTON, E.M., ... 1886.
Superintendent Establecimiento Mineral, Casapalca, Peru, South America.

Summer, 1886, New Jersey on Geological Work. 1886-87, in Cerra de Pasco, Peru, S. A. Assayer and Chemist to the commission examining that silver mining district. Spring, 1887, in New York, Chemist with Ledoux & Co. 1887-88, in Aurora, Ill., Assistant at the works of the Chicago and Aurora Smelting and Refining Company. Summer and fall, 1888, in Dutch Guiana, S. A., Assayer and Assistant in the examination of gold deposits. Fall, 1888 to 1893, in Aurora, Ill., Assistant Superintendent at the Aurora Works of the Chicago and Aurora Smelting and Refining Co. 1883, Superintendent Kootenay Reduction Co. 1894, Superintendent Balbach Smelting and Refining Co., Newark, N. J.

JOBBINS, F. H., PH.B., ... 1895.
284 Pearl Street, P. O. Box 2195, New York City.

1895-98, Jobbins & Van Ruymelke, Analytical Experts and Mfg. Chemists, Aurora, Ill. 1898, Treasurer and Secretary Alba Chemical Co., New York City.

JOHNSON, ARTHUR GALE, E.M., ... 1885.
Jensen, Utah.

JOHNSON, ELIAS MATTISON, PH.B., ... 1878.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, GILBERT HENRY, PH.B. . . . . 1878.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, ISAAC BRADLEY, E.M., ... 1879.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSTONE, WM. B., C.E., ... 1895.
47 Central Avenue, New Brighton, S. I., N. Y.

JONES, J. ELMER, E.M., ... 1893.
Assistant Superintendent Mill Creek Coal Co., New Boston, Pa., and Hazleton, Pa.

JOPLING, REGINALD FURNESS, E.M., ... 1889.
Jopling & Escobar, Engineers, Room 508 Cuyahoga Building, Cleveland, O.

November, 1889, to February, 1890, Chemist, Otis Steel Co., Ltd. February, 1890-92, Assistant Manager American Wire Co. Vice-President of same, January, 1892.

JOUET, CAVALIER HARGRAVE, PH.B., PH. D., . . 1882.
Columbia University and Roselle, N. J.

Analytical Chemist with Ledoux & Ricketts, 1882-85. Analytical Chemist with G. H. Nichols & Co., Acid Manufacturers at Laurel Hill, L. I., from 1885-88. Work comprising analyses of their various products and a partial supervision of their manufacture. Analytical Chemist from 1888 to 1896 with Ricketts & Banks. Analyst with Guggenheim Smelting Co., from March, 1896, to March, 1897. 1897-99, Instructor in Analytical Chemistry at Newark Technical School and Assistant in Analytical Chemistry at Columbia University.

K.

KASTNER, J. C., PH.B., ... 1894.
744 Broadway, New York City, and Oyster Bay, L. I., N. Y.

Member of firm of Julius Kastner & Sons, 1898.

KELLEY, WILLIAM, A.B., E.M., ... 1877.
President Lake Superior Mining Improvement, Vulcan, Dickinson, Co., Mich.

1876, '79, '80, Assistant Superintendent, Chemical Copper Co., Phœnixville, Pa. 1878, Chemist, Nimrod Furnace Co., Youngstown, Ohio. 1881-84, Superintendent, Kemble Coal and Iron Co., Riddlesburg, Pa.; 1885, Superintendent, Glamorgan Iron Co., Lewistown, Pa.; 1886-1889, Superintendent Kemble Iron Co., Riddlesburg, Pa. In charge of Blast Furnaces, Coal Mines, Coke Ovens, Ore Mines, Quarries, Railroads, etc. 1880 to date, General Superintendent and General Manager Penn Iron Mining Co., Vulcan, Mich.; in charge of Iron Ore Mines, on the Menominee Range, Lake Superior. Also, 1885-89, President Board of Examination of Bituminous Mine Inspectors of Pennsylvania. 1897-98, Member Board of Central Michigan College of Mines. President Lake Superior Mining Institute, 1898-99.

KEMP, JAMES FURMAN, A.B., E.M., ... 1884.
Professor Geology, Columbia University, School of Mines, and 211 West 139th Street, New York City.

Several months with the Rand Drill Co., 1883-1884. Private Assistant to Professor J. S. Newberry, 1884-1885. Student of Geology and Mineralogy at the University of Leipzig and Munich, Germany, 1885-86. Instructor in Geology at Cornell, 1886-88. Assistant Professor of Geology and Mineralogy, 1888-91, and Secretary of the Faculty, 1888-89. Have traveled much in the West, and for five summers past have been working on the Geology of the Adirondacks, chiefly as Assistant to the State Geologist, Professor James Hall. Am specially engaged on Inorganic and Economic Geology. 1891, Adjunct Professor of Geology, School of Mines, Columbia University. Professor, 1892. Secretary N. Y. Academy of Sciences since 1893. Editor *School of Mines Quarterly*, 1895-97. Manager Am. Inst. Mining Engrs, 1896-99. At work on Geology of Eastern Adirondacks for U. S. Geological Survey, August to September, 1896, also July to September, 1897. Also July to September, 1898.

KINSEY, FRANK WILMARTH, C.E., ... 1891.
Morris & Cummings Dredging Co., 22 State Street, New York City, and 58 Mt. Pleasant Avenue, Newark, N. J.

Assistant to Engineers Rapid Transit Commission, 1891–92. Engineer of Construction East Providence Water Works, 1892. Designing Engineer with S. M. Gray, 1892–93. 1893, Manager for R. W. Hildreth & Co. 1895, Assistant Superintendent Morris & Cummings Dredging Co.

KIPP, BURDETT, C.E., ... 1898.
20 West 121st Street, New York City.

KIRBY, G. T., E.E., ... 1895.
Attorney and Patent Lawyer, 2 Wall Street and 60 West 45th Street, New York City.

1888–89, Manager of Office of Pickles & Sutton, Architects, Tacoma, Washington.

KLEPETKO, FRANK, E.M., ... 1880.
Butte and Great Falls, Mont.

Superintendent Smelting Department Tamarack, Osceola Copper Manufacturing Company, Dollar Bay, Mich. 1896, Superintendent of Construction of the Great Falls Smelter, for the Boston and Montana Consolidated Copper and Silver Mining Company, Great Falls, Montana. 1897, General Manager Mines and Smelters of Boston & Montana Con. C. & S. Mg. Co., and Butte & Boston Con. Mg. Co.

KNOX, NEWTON B., A.B., E.M., ... 1897.
310 Pine Street, San Francisco, Cal.

KOEN, JOSEPH JOHN, C.E., ... 1888.
502 East 162d Street, New York City, N. Y.

1888–1889, Leveler and Topographer on New York City Croton Water Shed. 1890, to date, Sanitary Engineer on New York City Board of Health.

KUNHARDT, WHEATON BRADISH, E.M. (Life Member), 1880.
1 Broadway, New York City, N. Y.

1880–82, Travel and Study in the West and abroad. 1883–88, Engineer Bower-Barff Rustless Iron Co. and Assistant to George W. Maynard in consulting work, Ore-dressing. 1888–89, First Assistant Engineer Boston Heating Co. 1890–91, Diamond Drill Exploration of Coal Deposits in Rhode Island. Reports on Direct Steel Processes, Magnetic Separation Iron-ores and on Croton Magnetic Iron Mines. Acting Secretary of the American Institute of Mining Engineers for four months. 1893, President Osceola Placer Mining Co. 1895, Vice-President Carpenter Steel Co., 1 Broadway, New York City.

KURTZ, EDWARD LAURENCE, E.M., ... 1893.
Care Indiana Elect. Ry. Co., Elkhart, Ind., and 17 Pittsburgh Street, New Castle, Pa.

L.

LACOMBE, CHARLES FREDERICK, E.M., ... 1885.
The Mountain Electric Co., P. O. Box 1545, and 535–536 Seventeenth Street, and 1811 Grant Avenue, Denver, Col. Also, University Club, New York City.

1885–86, Assayer and Surveyor and Foreman of LuckyBoy and South Galena,

Mines, in Bingham, Utah. 1886-88, Assistant Instructor in Assaying, and Fellow in Chemistry, School of Mines, Columbia University, N. Y. 1888-90, Examining Gold and Silver Mines in Colorado, Utah, Montana, Arizona and Old Mexico. 1890, Testing Electrical Apparatus in Virginia City, Nevada. 1890, Manager of the Gilpin Co. Light, Heat and Power Co., Central City, Colo. 1890, to date, President and Manager, The Mountain Electric Co. Specialty, Installing Electric Light and Power Stations, and adapting electric light and power for mining purposes.

LADEW, J. HARVEY (Associate) (Life Member), . . 1885.
159 East Houston Street, and 813 Madison Avenue, New York City.

LAHEY, JOSEPH, E.M., ... 1887.
162 E. 86th Street, New York City.

LAHEY, RICHARD, E.M., ... 1887.
Millard & Lahey, 1429 Chestnut Street, Philadelphia, Pa.

LAMB, ANDREW JOHNSON, E.M., ... 1884.
L. & N. R. R. Co., Gallatin, Tenn.

June, 1884, to June, 1887, New York Croton Aqueduct, Draughtsman. June, 1887, to September, 1889, Assistant Engineer, L. & N. R. R. September, 1890, to June, 1891, Assistant Roadmaster, Knoxville Division, L. & N. R. R. June, 1891, to April, 1895, Assistant Engineer, L. & N. R. R. April, 1895, to date, Roadmaster, Main Stem, Second Division, L. & N. R. R.

LANGTHORN, JACOB S. (Associate), ... 1891.
Brooklyn Bridge Office, Washington Street, Brooklyn, and 79th Street between 3d and 4th Avenues, Bay Ridge, Brooklyn, N. Y.

1891, Surveying Land and R. R., Middlesborough, Ky., and Surveyor, Hondo Coal Co., Hondo, Coahuila, Mex. 1892, Draughtsman, Rapid Transit Comm., New York City, Craneman in Bessemer Mill, Carnegie Steel Co., Homestead, Pa. April, 1893, to October, 1893, Transitman R. R. Surveys on Long Island. October, 1893, to May, 1895, Elec. Insp., Foreman, Storekeeper, and Assistant Engineer, Brooklyn, Queens County, and S. R. R. Co. May, 1895, to Dec., 1895, Draughtsman, Rapid Transit Comm., New York City. Dec., 1895, to Jan., 1898, Assistant in charge of Docks and Bridges, Department of City Works, Brooklyn. June, 1898, to Sept., 1898, Boatswain's Mate, U. S. S. Elfrida. Jan., 1898 to date, Assistant Engineer, Department of Bridges, Borough of Brooklyn, New York City.

LAWRENCE, BENJAMIN BOWDEN, E.M., ... 1878.
Consulting Engineer, 810 Boston Building, and 1337 Gilpin Street, Denver, Colo.

1878-84, Superintendent Montezuma S. M. Co. and other mines of Summit County, Colo. 1884-89, Special work in Colo. 1889-97, Manager Dives-Pelican Mines, Georgetown, Colo., and Consulting Engineer, Denver, Colo.

LEARY, DANIEL JAMES, C.E., E.M., ... 1881.
43 East Twenty-fifth Street, New York City.

1882 to date, Constructing Highway and Railway Bridges, Wharves, Docks,

Dredging and Harbor Improvements generally, in vicinity of New York City, as Designing and Supervising Engineer, as well as Contractor in most instances. In general, make a specialty of both Engineering and Constructing work, or Engineering work alone, in this branch of the profession.

LEARY, GEORGE, C.E., ... 1891.
43 East Twenty-fifth Street, New York City.

LEBOUTILLIER, CLEMENT, PH.B., ... 1881.
High Bridge, N. J.

1884-7, Assistant Chemist, Cambria Iron Co. 1887-92, Chemist Eliza Furnace. March, 1892, to date, Chemist, Taylor Iron and Steel Company.

LEDERLE, ERNST JOSEPH, PH.B., ... 1886.
Chief Chemist, New York City Health Department, Criminal Court Building, Centre and Franklin Streets, and 471 W. 143d Street, New York City.

1886-87, Hon. Fellow Quant. Anal. and Assist. Instr. Gen. Chemistry, School of Mines. 1887-88, Chemist, Cranmoor Farm, Tom's River, N. J. 1888-89, Assistant Chemist, New York City Health Dept. 1890-91, Chemist and Supt., Reed & Carnick, New York. 1891 to March, 1896, Assist. Chemist, New York City Health Dept. March, 1896, to date, Chief Chemist, also consulting Chemist to Health Officer, Port of New York.

LEDOUX, ALBERT REID, M.S., PH.D. (Associate), . 1874.
99 John Street, and 39 W. 50th Street, New York City.

LEE, GEORGE BARSTOW, E.M., ... 1885.
Superintendent Arkansas Smelting Co., Leadville, Colo.

1885, Assayer, Butte, Montana. 1886-87, Assayer, Kansas City Smelting and Refining Co., Argentine, Kan. 1887-90, Assistant Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1890-93, Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1894, Superintendent, Guggenheim Smelting Co. 1896, Superintendent, Union Smelting Co., Leadville, Colo. 1897, to date, Superintendent, Arkansas Valley Smelting Co., Leadville, Colo.

LEGGETT, THOMAS HAIGHT, E.M., ... 1879.
P. O. Box 485, Johannesburg, S. A. Rep.

1880 Assistant Engineer New York River and Harbor Surveys. 1881-83, Superintendent of Mining Properties in the Batopilas District, Chihuahua, Mexico. 1884, Travelling in the West, through the principal Mining Camps, Butte, Leadville, etc. 1884-87, Mining Engineer to the New York and Honduras Rosario Mining Co., at San Juancito, Honduras. 1888, Manager of Mudsill Mining Co., Fairplay, Colo.; office, 23 Bucklersbury, London, E. C. 1889-90, General Manager, Darien Gold Mining Co., Ltd., of Cana, Rep., of Colombia. 1891-95, President and Manager, Standard Consolidated Mining Co. Consulting Engineer S. Neuman & Co., of London and Johannesburg since July, 1895.

LENOX, LIONEL REMOND, PH.B., ... 1888.
Professor of Analytical Chemistry, Leland Stanford, Jr., University, Palo Alto, California.

LEVINE, EDMUND J., B.S., ... 1898.
Care of The Fiberloid Company, 636 Broadway and 340 West 88th Street, New York City.

LEVY, ALBERT LINCOLN, E.M., ... 1890.
149 Franklin Street and 810 Lexington Avenue, New York City.

LEWIS, CLARENCE MCKENZIE (Life Member), C.E., . 1898.
104 East 37th Street, New York City.

LIBAIRIE, EDWARD WILLIAM, C.E., ... 1894.
2098 Boulevard and 150 W. Forty-ninth Street, New York City.

LIEBMANN, ALFRED, C.E., ... 1893.
50 Broadway, and 38 E. Seventy-second Street, New York City, Member of Firm of R. W. Hildreth & Co.

LILLIENDAHL, ALFRED WHIPPLE, E.M. (Life Member), 1883.
Superintendent, Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico, and Lakewood, N. J.
1883-85, Assistant Supt. Aurora Smelting and Refining Co., Aurora, Ill. 1885-87, Assistant Supt. Grande Milling and Refining Co., Guanajuato, Mexico. 1888-97, Superintendent of the Mazapil Copper Co., Ltd., Concepcion del Oro, Zacatecas, Mexico. Superintendent Coahuila and Zacatecas Railroad.

LILLIENDAHL, FRANK ARMSTRONG, E.M., . . . 1891.
Assistant Superintendent and Metallurgist Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico (via Laredo, via Saltillo).
1891-97, as above.

LILLIE, SAMUEL MORRIS, E.M., ... 1874.
328 Chestnut Street, Philadelphia, Pa.
1874-75, Chemist, Kings County Refining Co., Green Point, L. I. 1876-85, Chemist, Franklin Sugar Refinery, Philadelphia, Pa. 1886-87, Sugar Engineer and Chemist. 1888-90, Vice-President and Manager of "The Sugar Apparatus Manufacturing Co." a company organized under the laws of Pennsylvania, to be operated under his patents. 1891, President of said Company.

LIPPS, HENRY, JR., C.E., ... 1888.
Elliott Avenue, Williams Bridge, New York City.
From July, 1888, to August, 1889, Assistant Engineer Maintenance of Way Dept. R. & D. R. R., W. N. C. & Va. Mid. Div. August, 1889, to January, 1890, Supervisor Track, N. C. Div. R. & R. R. January, 1890, Engineer Maintenance of Way, N. C. Div. R. & D. R. R.

LITTLE, WILLARD PARKER, E.M., PH.B., . . . 1881.
Little & O'Connor, Architects, Astor Court Building, 20 West Thirty-fourth Street, New York City.

LIVINGSTON, ARCHIBALD ROGERS, C.E., . . . 1891.
20 North Washington Square, New York City.
Since November, 1891, in employ of Lackawanna I. & S. Co., Scranton, Pa.

LONGACRE, LINDSAY B., M.E., B.D. (Drew Theol.), . 1892.
108 West 41st Street, New York City, and Spuyten Duyvil, N. Y.
Graduated with class of 1896, Drew Theological Seminary. Methodist Pastorate, St. Luke's New York.

LORD, FREDERICK REUBEN, C.E., ... 1892.
Member of Firm, F. J. Lord & Co., Steamship Agents and Ship Builders, 27 William Street, New York City, and Stapleton P. O., Richmond Co., N. Y.

LOVE, EDWARD GURLEY, A.M., PH.B., PH.D., . . 1876.
Analytical and Consulting Chemist, Gas Examiner, Department Public Works, 125 Bowery, and 80 East 55th Street, New York City.

LOWENSTEIN, JOSEPH, PH.B., ... 1896.
205 Belmont Avenue, Newark, N. J.

LOEWENTHAL, MAX, E.E., ... 1897.
Associate Editor, *The Electrical Engineer*, 120 Liberty Street, and 1057 Lexington Avenue, New York City.
From 1894–98, Instructor in Mechanical Drawing in the evening schools of The General Society of Mechanics and Tradesmen. 1897–98, Instructor in Electrical Engineering in The United Correspondence Schools, 156 Fifth Avenue, New York. Formerly Editor of *The Technical Journal*. 1898, Asso. Editor *The Electrical Engineer*.

LOWTHER, C. M., E.E., ... 1898.
Stabic Carbonating Co., 8 East 42d Street, Riverside, Conn.

LUDLAM, FRANK (Associate), ... 1895.
Department of Buildings, 220 4th Avenue, and 8 West 16th Street, New York City.
1896, with Hines & La Fargo and since January, 1897, connected with Dep't. Buildings, New York City.

LUDLOW, EDWIN, E.M., ... 1879.
Superintendent of Mines, Choctaw, Oklahoma & Gulf R. R., Hartshorn, Indian Territory.
1879–81, Assistant Engineer in charge of hydrographic work on Delaware River under U. S. Engineer. 1881, Assistant Engineer Mexican National Railroad, Mexico. 1882–89, Assistant Superintendent, then Superintendent, for Pennsylvania Railroad coal mines at Shamokin, Pa. 1889, to date, Superintendent of Mines, Choctaw Coal and Railroad Company, Hartshorn, Indian Territory.

LUQUER, LEA MCILVAINE, C.E., PH.D. (1894), . . 1887.
Tutor in Mineralogy, Columbia University, and 321 West 80th Street, New York City.
Summer of 1897, Assistant in Geodetic Surveying with Professor Rees. Summer of 1897, Assistant in Surveying with Professor Munroe. Summer of 1888, Assistant in Geodetic Surveying with Professor Rees. 1887–90, Fellow in Mineralogy, School of Mines. 1890, Assistant in Mineralogy, School of Mines. 1891

to date, Tutor in Mineralogy, Columbia University. 1895-96, Lecturer and Instructor in Mineralogy during absence of Professor Moses in Europe.

LUQUER, THATCHER TAYLOR PAYNE, C.E., E.E. (1893), 1889.
New York Telephone Co., 15 Dey Street, New York City.

1890, Fellow in Engineering. 1890-91, Fellow in Surveying and Practical Mining. 1891, Assistant in Mining, Columbia University, School of Mines. 1892, with H. Ward Leonard & Co., New York City. 1893, Engineer, Union Electric Co., New York City. 1894, Engineer Fibre Conduit Company; New York City. 1895, Engineering Dept. Met. Tel. and Tel. Co., and 1896, Engineering Dept. New York Telephone Co.

LUSK, GRAHAM, A.M., PH.B., PH.D., . . . 1886.
New York University and Bellevue Hospital College, and 47 East Thirty-fourth Street, New York City.

1887-88, Student at Munich. 1889, Student at Munich; also at Bellevue Hospital Medical College, New York. 1890, studied at Bellevue; afterwards in Munich. 1891, studied in Munich and was later appointed Instructor of Physiology at the Yale Medical School. 1892, Assistant Professor of Physiology. 1895, Professor of Physiology. 1896, contributed the chapter "The Chemistry of the Animal Body" to the American Text-book of Physiology. 1897, Professor of Physiology at the Yale Medical School. 1898, appointed Professor of Physiology, New York University and Bellevue Hospital Medical College.

LYDECKER, IRVING SMITH, E.M., ... 1898.
Joplin, Mo.

LYMAN, FRANK, A.B., M.E., ... 1878.
31 Burling Slip, New York City, and 39 Remsen Street, Brooklyn, N. Y.

Treasurer The Low Moor Iron Co. of Va.

M.

MCCAFFERY, RICHARD S., E.M., ... 1896.
316 E. 124th Street, New York City.

MCCLELLAND, J. BRUCE, B.S., A. M., . . . 1897.
2 West 47th Street, New York City.

MCCONWAY, WILLIAM, JR., E.M., ... 1896.
The Conway & Torley Co., 48th Street, and A. V. Ry. and Bedford Avenue, Pittsburg, Pa.

MCILHINEY, PARKER C., A.M., PH.D., . . . 1892.
School of Mines, Columbia University, and 320 St. Nicholas Avenue, New York City.

Summer of 1892, Chemist Fibre Pipe Co. 1893-94, Hon. Asst. in Assaying. 1894, Asst. in Metallurgy.

MCKENNA, CHARLES FRANCIS, PH.B., . . . 1883.
221 Pearl Street, and 155 West 91st Street, New York City.

1883-84, Chemist, Havemeyer Sugar Refining Co., Jersey City, N. J. 1885-86,

Chemist, Cambria Iron Co., Johnstown, Pa. 1887-90, Engaged in the manufacture of lime for gas purification, Edgewater Lime Works, Edgewater, N. J. 1891-93, with Jas. J. McKenna & Bro., Founders, New York City. 1893, Associated with Dr. Gideon E. Moore, New York City, as Director of the Laboratory of Physical Testing. 1895-97, Chemist to the Passaic Zinc Co., Practising as consulting chemist and inspector of materials.

McKim, Alex. Rice, B.S. (Mass. Inst. Tech.), A.M. . 1897.
106 East 23d Street, New York City.

Graduated as Civil Engineer Mass. Inst. of Technology (B. S.), Technische Hochschule, zu Berlin, two years. School of Architecture at Columbia University, (A. M.). Old Colony Railroad, Construction. Edge Moor Bridge Works, Bridges. Berlin Bridge Co., Building Construction. J. B. & J. M. Cornell, Building Construction. Since May, 1895, Consulting and Expert Architectural Engineer.

McKim, Robert Albert, C.E., ... 1884.
Room 213, 280 Broadway, and 30 West 18th Street, New York City.

Assistant Engineer on New Croton Aqueduct. (Entered Aqueduct Engineer Corps as Chairman, in February, 1885.)

McKinlay, Wm. Bradford, E.M., ... 1895.
Care Wm. Jarvis, Tumaco, Rep. Colombia, South America.

Assistant at Pelican-Dives Mine, Georgetown, Colo., October-December, 1895. Mine Clerk at Peerless Coal Mine, Aguilar, Colo., December, 1895, to February, 1896. General Assay Office at La Belle, Toas, Co., New Mexico, May to November, 1896. March, 1897, to date, Assistant Engineer Playa de Oro Mining Co., Ecuador, S. A.

McLaughlin, Charles Swain, Ph.B., . . . 1884.
890 Broadway, New York City.

MacKaye, Harold Steele, C.E., ... 1887.
29 Liberty Street, and 225 West 106th Street, New York City.

Three months' work in New York Harbor in Army Corps of Engineers. One year's employment in the Office of Patent Solicitors. 1889-92, acting as Fourth Assistant Examiner of the U. S. Patent Office. Since July, 1892, Patent Counsel for Westinghouse Electric and Manufacturing Co. In independent practice as patent lawyer since November, 1, 1896.

MacLay, James, C.E., ... 1888.
Instructor in Mathematics, Columbia College, and 87 Union Street, Newark, N. J.

Mahony, Arthur Stuart, E.M., ... 1889.
51 West 94th Street, New York City.

1890, First Assistant General Manager of the New Birmingham Iron and Land Co. 1891, Treasurer of the same company, also Chemist to the Tassie Belle Furnace, New Birmingham, Texas. 1893, contractor.

Malukoff, A. J., ... 1893.
Department of Bridges, 177th Street and 3d Avenue, and 72 West 131st Street, New York City.

MANNHEIM, HERMANN CHARLES, E.M., . . . 1887.
Care of Simmer & Jack G. M. Co., Germiston, S. A. R.

MANNHEIM, PAUL AUGUST LOUIL, E.M., . . . 1885.
Smelter, Montana Smelter, Cascade Co., Montana.

MARIE, LEON, E.M., ... 1885.
152 West 86th Street, New York City.

MARSH, JOHN ROLLIN, E.M., ... 1887.
Address unknown.

MARTIN, EDWARD WARD (Associate), . . . 1877.
Chemist, Board of Health, 301 Mott Street, New York City.

MARTIN, L. TROWBRIDGE, E.E., ... 1897.
114 East 36th Street, New York City.

MASSA, CHARLES GRISWOLD, C.E., ... 1889.
Fort Lee, N. J.

Since October, 1889, on varied engineering work, including: Topographical Survey, Greenwood Lake, N. Y., 1889; Structural Steel Shop Inspection with R. W. Hildreth & Co., at Phœnixville, Pa., 1890, and at Harrisburg, Pa., 1894; Construction Lehigh Valley Ry. Extension, Geneva, N. Y., 1890; Steel Railway Construction, Allegheny, Pa., 1890-91; R. of W., Maintenance, Construction, Northwestern System, Penna. Lines. 1891-93; Construction, Masonry, Dam, Etc., Newton, N. J., Water Works, 1895. On Chatham, N. J., Water Works, 1897, and similar work to date.

MASSA, LOUIS FERDINAND, C.E., ... 1890.
136 Liberty Street, New York City, and Fort Lee, N. J.

October, 1890–92, shop practice, Maryland Steel Works, at Sparrow's Point, Md., as follows: October, 1890, to July, 1891, Machine-shop practice. July, 1891, to September, 1891, Bessemer Mill Construction. September, 1891, to September, 1892, Bessemer Rail-mill and Roll-house; Mechanical and Metallurgical Engineering. October, 1892-93, Post-graduate Electrical Engineer at Columbia College. February, 1894, to date, Electric Engineering, Construction and Constructing.

MASTERS, H. K., E.M., ... 1894.
Nichols Chemical Co., Laurel Hill, L. I., N. Y., and 285 Quincy Street, Brooklyn, N. Y.

MATHEWS, JOHN ALEX., B.S., M.S. (Washington), A.M., PH.D., ... 1895.
College of Physicians and Surgeon, New York City, and 4 First Place, Brooklyn, N. Y.

Assistant in Assaying, Columbia University, 1896-97; Fellow in Chemistry, 1897-98; Tutor in General Chemistry, 1898; Fellow of the Chemical Society, London; Member of the American Chemical Society.

MATHIS, THEOPHILUS SMITH, E.M., ... 1879.

49 South Main Street, and 52 East Ninth Street, Salt Lake City, Utah.

From January, 1890, to February, 1891, Assistant Draughtsman U. S. Surveyor-General's Office, Salt Lake City, Utah. From February, 1891, to August, 1893, Chief Draughtsman of Mineral Division of said office. From August, 1893, to date, engaged in General Mining Engineering Work.

MAYER, RALPH EDWARD, C.E., ... 1879.

Instructor in Mechanical Drawing, Columbia University, New York City.

MEISEL, F. C. A., PH.B., ... 1892.

44 Strong Place, Brooklyn, N. Y.

1892-93, 1st Asst. Chemist National Lead Co. 1893-94, Chemist, International Phosphate Co. 1895 to 1897, Examiner Chemist, U. S. Laboratory.

MEISSNER, CARL AUGUST, PH.B., ... 1880.

General Manager Londonderry Iron Company, Londonderry, Nova Scotia.

One year, Assistant Chemist Joliet Steel Co. Three years, Chemist and Assistant Superintendent Brier Hill Iron and Coal Co., Youngstown, Ohio. One and a-half years, Head Chemist Joliet Steel Co. Three years, Manager Sterling Iron and R'wy Company, Sterlington, N. Y. At present, Vice-President and General Manager of the Vanderbilt Steel and Iron Company, Birmingham, Ala., after having personally organized this company. President Jefferson County Mining and Quarrying Company.

MELLISS, D. ERNEST, A.M., PH.D. (Associate), . . 1868.

Consulting Engineer, 524 Sacramento Street, San Francisco, Cal.

Student regular course, three years, School of Mines. Afterwards, two and a-half years University of Göttingen, graduating Ph.D., in 1869. One year at University of Vienna. Since then, constantly occupied in civil and mining engineering. In 1873 was Chief Engineer in charge of Topographical and Geological Survey of Guanocaste and Nicoya for the Costa Rican Government. In 1881, Consulting Engineer to the Pacific Gas Light Company, of San Francisco, and in its interest studied the different gas-making systems in the United States, England, France and Belgium. Have made plans, reported upon and erected numerous gold, silver, copper and lead mines. Planned the Union Iron Works of San Francisco, and superintended their construction ; also, the Arctic Oil Works and several other industrial establishments on the Pacific Coast. Designed and built the Mazatlán Water Works, in Mexico ; the Hydraulic Press Brick Works, of California, the largest establishment of its class on the Pacific Coast. Four years in Central America and Mexico. Was Administrator of San José de las Bocas and Consulting Engineer to Guadalupe de los Reyes, the most successful silver mine of Sinaloa. Now Consulting Engineer in San Francisco, and particularly occupied in that capacity for the Olympic Salt Water Co., whose works are now being erected under his supervision and according to his plans. Planned and built the Olympic Salt-Water Co.'s Works, San Francisco, Cal. 1894-97, Superintendent of Works, San Francisco, New City Commission. Fall, 1897, investigating hydraulic questions in Venezuela.

MENLINE, ISAAC, C.E., ... 1898.
The Johnson Company and Hotol Topliff, Loraine, Ohio, also, 356 East 69th Street, New York City.
Since October, 1898, to date, with the Johnson Co., Lorain, Ohio.

MERRILL, FREDERICK JAMES HAMILTON, PH.B., PH.D., 1885.
State Museum, and 268 State Street, Albany, N. Y.
1885 to 1887, Assistant on the Geological Survey of New Jersey. 1886 to 1890, Fellow in Geology, Columbia College School of Mines. 1890 to 1893, Assistant State Geologist of New York. 1890 to 1894, Assistant Director of the New York State Museum. 1892-93, Director of the Scientific Exhibit of the State of New York at the World's Columbian Exposition. 1894 to date, Director of the New York State Museum, Albany, N. Y.

MERRITT, JAMES HAVILAND, PH.B., A.M., . . . 1880.
3 Monroe Place, Brooklyn, N. Y.
From 1881–88, Chemist to the Bradley White Lead Co. In 1889, entered the School of Mines as Post-graduate in the course of Architecture. 1892–93, Architectural Study.

MERZ, EUGENE, E.M., ... 1892.
Box 216 and 143 Littleton Avenue, Newark, N. J.
Assistant Superintendent American Ultra Marine Works.

MESEROLE, WALTER MONFORT, C.E., . . . 1881.
189 Montague Street, and 2789 Atlantic Avenue, also 288 Hancock Street, Brooklyn, N. Y.
1881, Transitman and Topographer Continental Railway Co. 1881–83, Assist. Eng. in Construction, N. Y., West Shore and Buffalo Ry. 1884–85, Division Engineer Maintenance of Way; 1885, Chief Engineer Catskill Mountains and Cairo Railway. 1885, in charge Topographical Survey for Kings County Charities Commission. 1886 to date, in General Practice, located at Brooklyn, N. Y. Specialties: Improvement and Development of Real Estate and Surveying for Legal and Construction Purposes; City Surveyor of the City of Brooklyn; Chief Engineer South Brooklyn R. R. and Terminal Company, German-American Improvement Company and Hancock and State Line Railway Company. Erie and Central New York Ry. Co. Engr. Commission Atlantic Avenue Improvement, Brooklyn, N. Y.

MESSITER, E. H., C.E., ... 1894.
Arkansas Valley Smelting Co., Leadville, Col., and 161 West 108th Street, New York City.
1889, Draughtsman New Croton Aqueduct. 1891 (Summer vacation), Draughtsman Mfg. Investment Co., Madison, Me. Mill Construction, June, 1894, to November, 1894. Inspector under Wm. Barclay Parsons, C.E., November, 1894. June, 1895, Engineer Guggenheim Smelting Co., Perth Amboy, N. J. June, 1895, to January, 1896, Chief of Party, Surveys for Rapid Transit Commission, New York City. January, 1896, to November, 1896, Engineer Guggenheim Smelting Co., Perth Amboy, N. J. November, 1896, to April, 1897, Engineer Philadelphia Smelting and Refining Co., Pueblo, Col. April, 1897, to date, Engineer Arkansas Valley Smelting Co., Leadville, Col.

MEYER, HERMAN HENRY BERNARD, E.M., ... 1885.

Brooklyn Union Gas Company, Nevens and Degraw Streets, and *for Mail* 844 Putnam Avenue, Brooklyn, N. Y.

Surveying, Field and Office Work at Pelham Park, Westchester Co., July to November, 1885. December, 1885, to date, Engineer for Oregon Iron Works, New York; designing and erecting machinery for manufacturing illuminating gas.

MIDDETON, JOHN, C.E., ... 1887.

2789 Atlantic Avenue, and 189 Montague Street, Brooklyn, N. Y.

1888-97, Surveyor Assistant to W. M. Meserole, C.E.

MILLER, CHARLES LEWIS, E.M., ... 1885.

Illinois Steel Company, and 707 Collins Street, Joliet, Ill.

1886, Assistant Chemist Edgar Thomson Steel Works, Braddock, Pa. 1886-87, Chemist and Assistant Superintendent Carbon Iron and Pipe Co., Perryville, Pa. 1887-90, Superintendent The Missouri Furnace Co., St. Louis, Mo. 1890 to 1896, Superintendent Blast Furnaces at Union Works of Illinois Steel Co., Chicago, Ills. Since August, 1896, General Superintendent Union Works, Ill. Steel Co., Chicago, Ill. Since August, 1897, General Superintendent Joliet Works, Ill., Steel Co.

MILLER, CHARLES WATTS, E.M., ... 1884.

Assistant Manager Silver Lake Mines, Silverton, Colo.

1884-85, Metallurgical Engineer Hecla Bronze and Iron Works. 1885-86, Assayer and Chemist, Aspen, Col. 1886-91, Mining Engineer and United States Deputy Mineral Surveyor, Aspen, Col. General mining engineering business. 1898, Assistant Manager Silver Lake Mines, Silverton, Colo.

MILLER, EDMUND HOWD, PH.B., A.M. (1892), PH.D. (1894), ... 1891.

Instructor in Analytical Chemistry and Assaying, Columbia University, and West Nyack, Rockland Co., N. Y.

1891-94, Assistant in Assaying. 1894-97, Tutor in Analytical Chemistry and Assaying. 1897, as above.

MILLER, RUDOLPH PHILIP, C.E., ... 1888.

141 East Fortieth Street, New York City.

1888-1890, Assistant to E. M. W. 1890-94, Supervisor R. & D. Railway till April, 1894. August to November, 1894, with W. S. Miller, Builder, New York City. November, 1894, to October, 1895, with Long Island R. R. as Transitman and Assistant. December, 1895, to date, with Department of Buildings, New York City.

MILLER, SAMUEL O., C.E., ... 1895.

Columbia University, New York City, and West Nyack, N. Y.

From June to September, 1895, field and office work for Ramapo Water Co. January to March, 1896, engaged in Mine Surveying for the Sterling Iron and R. R. Co., Sterling, N. Y. From March, 1896, to date, in the employ of the Department of Buildings of New York City. 1897 to 1898, Assistant Engineer, Department of Buildings, New York City. Assist. in Mech. Engineering, Columbia University.

MOELLER, EDGAR J., PH.B., ... 1895.
3 River View, Terrace, New York City.

MOLDEHNKE, RICHARD GEORGE GOTTLOB, E.M., PH.D., 1885.
McConway & Torley Co., Forty-eighth Street, and A. V. R. R., and 174 Home Street, Pittsburgh, Pa.

1885-87, Three Summer seasons with United States Coast and Geodetic Survey, New York and Philadelphia Harbors and Cape Cod, Mass., *Hydrographic Work*, Triangulation, Levelling, etc. 1885-86, Winter, nine months, *Sanitary Engineering*, Inspector, etc., New York Association for Improvement of Condition of Poor. 1887-89, *Electrical Engineering*, five months Mining Engineer Sprague Electric Railway and Motor Co., seven months Mechanical Engineer Crocker-Wheeler Motor Co., five months experimenting on patents taken out. 1889, Manufacturing for myself. Specialty in Machinists' Tools. 1889-90, Professor Mechanical and Electrical Engineering, Michigan Mining School, Houghton, Mich. 1890, to date, Engineer McConway & Torley Co. Expert in Malleable Castings.

MONELL, JOSEPH THOMPSON, C.E., ... 1889.
136 Liberty St., and 236 W. Twenty-second St., New York City.

1891, Electrical Engineering, Curtis Electrical Mfg. Co. 1892, Tutor in Astronomy, Columbia College.

MONKS, RICHARD A. (Associate), ... 1894.
130 Water Street and 71 Lexington Avenue, New York City.

MONTENEGRO, MANUEL RAFAEL, E.M., ... 1890.
539 W. Twentieth Street, New York City.

1890, Spiral Weld Tube Company, East Orange, N. J., and studying machine-shop practice. 1891-92, engaged in the formation of mining companies. 1892 to date, Assistant Superintendent Oregon Iron Works, New York City.

MORA, MARIANO LUIS, C.E., ... 1891.
General Electric Company, Foreign Department, 44 Broad Street, and 63 West 70th Street, New York City.

Graduate Post-graduate Course Electrical Engineering, 1894.

MORAN, DANIEL EDWARD, C.E., ... 1884.
John Monks & Son, 130 Water Street and 71 Lexington Avenue, New York City.

MORGAN, WILLIAM FELLOWES, A.B., E.M. (Life Member), 1884.
Brooklyn Bridge Freezing and Storage Co., Arch 4, Brooklyn Bridge, New York City, and Short Hills, N. J.

1884-88, Banking and Brokerage. 1888, to date, as above.

MOSLEY, RICHARD KELLER, PH.B., ... 1889.
Architect, Room E, 22, Produce Exchange Building, New York City, and 139 Glenwood Avenue, East Orange, N. J.

From June, 1889, to January, 1893, worked as Draughtsman in the Office of L. J. O'Connor, Carrère & Hastings, and Richard M. Hunt, of New York, and Benj. Silliman, of Yonkers, N. Y. Since January, 1893, practicing Architecture independently at the above address.

MOSES, ALFRED JOSEPH, E.M., PH.D., . . . 1882.

Professor Mineralogy, Columbia University School of Mines.

1882–85, Assistant in Mineralogy, School of Mines. 1885–90, Instructor in Mineralogy and Metallurgy. 1890 to 1897, Adjunct Professor of Mineralogy.

MOSES, PERCIVAL ROBERT, E.E., ... 1895.

35–37 Nassau Street, New York City.

MULFORD, ROBERT, E.M., ... 1884.

Manager Fraser & Chalmers, 80 Broadway, New York City, and 144 S. Second Avenue, Mt. Vernon, N. Y.

1890, Assistant Superintendent Rio del Oro Gold Co., Argentine Republic, S. A. 1891, Honduras. 1893, General Manager of The Kanimpoo Gold Mining Co., Limited, of Georgetown, Demarara, British Guiana, and am now in the employ of Fraser & Chalmers.

MÜLLER, GEORGE, PH.B., ... 1887.

634 East One Hundred and Thirty-ninth Street, New York City.

MUNROE, HENRY SMITH, E.M., PH.D., . . . 1869.

Professor of Mining, School of Mines, and Dean of the Faculty of Applied Science, Columbia University, and 45 Sidney Place, Brooklyn, N. Y.

1869–70, Post-Graduate Student in Chemistry and Economic Geology, School of Mines. 1870–71, Assistant Geologist Ohio State Geological Survey. 1870–72, Assistant Chemist, Department of Agriculture, Washington, D. C. 1872–75, Assistant Geologist and Mining Engineer, Geological Survey of Yesso, Japan. 1875–76, Professor of Geology and Mining, University of Tokio, Japan. 1877–91, Adjunct Professor of Surveying and Practical Mining, and 1891, Professor of Mining, School of Mines, Columbia University, New York City. 1881–85, Manager, and 1890–92, Vice-President American Institute Mining Engineers. 1895, to date, Member of the University Council, and 1897, Dean of the Faculty of Applied Science, Columbia University.

MUNROE, OTIS MORTIMER, PH.B., ... 1879.

Banker, De Soto, Mo.

MUNSELL, CHARLES EDWARD, PH.B., PH.D., . . 1878.

F. W. Devoe & C. T. Raynolds Co., 110 Horatio Street, New York City, and Rye, N. Y.

November, 1878, with E. A. Foote, Mineral Dealer, Philadelphia. March, 1879, with T. A. Edison, Menlo Park, N. J. May, 1879, Chemist, Bushwick Chemical Works, Brooklyn, N. Y., October, 1879, Stencilographer and Celestyper, School of Mines, N. Y. January, 1880, to December, 1885, Milk Inspector, New York City Health Department. July, 1881, to May, 1883, State Milk Inspector, New York State Board of Health. 1886 to 1895, Analyist and Assistant Chemist, F. W. Devoe and C. T. Raynolds Co., New York City. Specialty, Paints and Colors.

MURPHY, HENRY MORGAN, E.M., ... 1878.

Murphy Varnish Co., Chestnut and McWhorter Streets, Newark, N. J.

N.

NAVARRO, JOHN ADALBERT, C.E., ... 1880.
Seminario No. 1, Mexico City, Mexico, and care Mexico Consul-General, 35 Broadway, New York City.

1881–82, Civil Engineering Course in Polytechnium, Hanover, Germany, 1882–84, Mexican Government Commissioner to study railway systems of Europe. 1885–6, Railroad Inspector in Interoceanic Railroad, Mexico. 1886–87, Assistant Compiler of Memoir, published by Department of Public Works (*Fomento*), Mexico. 1887 to date, Engineer in charge of Surveys and Representative in Chiapas of the Mexican Land and Colonization Co.

NESMITH, JAMES, E.M., ... 1879
256 Henry Street, Brooklyn, N. Y.

NEWBROUGH, WILLIAM, A.B., E.M., ... 1884.
122 West 34th Street, New York City.

NICHOLS, RALPH, E.M., C.E., ... 1877.
Superintendent De La Mars, Nev. G. Mg. Co., Delamar, Lincoln Co., Nevada.

1878, Ore Sorter, Hukill Mine, Idaho Springs, Colo. Later, Assistant in F. E. Brown's Civil and Mining Engineering office, Georgetown, Golo. Later, Assayer and Chemist La Plata M. and S. Co., Leadville, Colo. Appointed U. S. Deputy Mineral Surveyor in 1879. 1879–82, Civil and Mining Engineer at Leadville, Colo., with following firms: Page, Nichols & Co., and Nichols & Dunham. Superintendent Farwell Con. Mining Co.'s Gold Mill at Independence, Colo. Superintendent of the Big Pittsburg Cons. Mining Co., Leadville. 1883, Superintendent of the Viola Mining and Smelting Co. Later General Manager of same until 1891. Since then have been mining and working mines on lease. Examined mines in Colorodo, Idaho, Nevada and Mexico. 1894, General Superintendent The Comstock Tunnel Co. Interested in Mines in Colorado and Idaho, and am working mines in Idaho under lease. Have acted as ore buyer for the Cons. Kansas City S. and R. Co., and am at present representing the Globe S. and R. Co., in this State.

NOLAN, THOMAS M.S., PH.B., ... 1884.
College Hall, University of Penn., Philadelphia, Pa.

Practicing Architecture, 1884–96, in Rochester, N. Y., and in New York City, 1896-98. Post Graduate Work in Architectural Engineering Columbia University, 1897-98. Appointed Instructor in Architecture, University of Pennsylvania, September, 1898.

NORRIS, ROBERT VAN ARDSDALE, E.M., . . . 1885.
Assistant Engineer P. R. R. Department of Anthracite Coal, Room 28 First National Bank Building, and 24 S. Franklin Street, Wilkesbarre, Pa.

1885, Assistant in Practical Mining and Surveying, School of Mines. U. S. Inspeetor of Dredging, in charge of Maurice River Improvement, Millville, N. J. 1886, Chemist, Herman Behr, Manufacturer of Colors, Brooklyn, N. Y. June, 1896, to date, Assistant Engineer, Pennsylvania Railroad Department of Anthracite Coal Collieries. Specialty, Mechanical Engineering of Collieries.

NORTON, LUCIEN HOLLEY, E.M., ... 1886.
Pennsylvania Smelting Co., Sandy, Utah.

1887–1890, Engineering Office, N. Y., N. H. & W. R. R. Experience in Railroad Construction, Location and Preliminary Surveys, Office Works and General Surveying. 1890, Assayer and Engineer to West Indian New Gold Mining Corporation, San Domingo, West Indies. Experience in Free Melting of Gold ores, Assaying, Surveying, etc. January, 1891–92, Assayer for Daly Mining Co., Park City, Utah. Experience in Assaying, General Analyses. Also Leaching of Silver ores by the Russell Process. 1892, to date, as above.

NOYES, JAMES ATKINS, PH.B., A.B. (Harvard, '83), (Life Member), ... 1878.
71 Sparks Street, Cambridge, Mass.

Editor Quinquennial Catalogue, Harvard University.

NOYES, WILLIAM SKAATS, E.M., ... 1875.
Shafter, Presidio County, Texas, and 2023 Summit Street, Oakland, Cal.

1877–79, Assayer for McCrackin Mining Co., Mohave Co., Arizona. 1897–1881, Foreman of Bodie Mill, for Bodie Coal Mining Co., Bodie, Cal. 1881–1883, Examining Mines for San Francisco Capitalists. 1883 to present time, Superintendent of Presidio Mining Co., and The Cibilo Creek Mill and Mining Co., Shafter, Presidio Co., Texas.

NYE, ALVAN CROCKER, PH.B., ... 1884.
Hayden Furniture Co., 1 West Thirty-fourth Street, and 1143 Lexington Avenue, New York City.

1884–85, Draughtsman C. C. Haight, Architect, New York City. 1885–90, Designer and Head Draughtsman, Herter Brothers, New York City. 1898 to date, Furniture Designer and Architect, the Tiffany Glass Co., New York City. 1892, Chief Designer as above.

O.

O'CONNOR, MICHAEL JOSEPH, E.M., PH.B., . . 1881.
Little & O'Connor, Architect (1884) the Astor Court Building, 20 West Thirty-fourth Street, New York City.

O'CONNOR, THOMAS DEVLIN, PH.B., . . . 1881.
Aldrich Court, 45 Broadway, Room 91, and 12 E. Forty-fourth Street, New York City.

OF, CHARLES, E.M., ... 1896.
802 Prospect Avenue, New York City, N. Y.

OLCOTT, EBEN ERSKINE, E.M., ... 1874.
Mining and Metallurgical Engineer, 18 Broadway, and 38 West Thirty-ninth Street, New York City.

1874–75, Chemist to Ore-Knob Copper Co., in charge of Hunt & Douglas Process. 1875–76, Assistant Supt. Penna. Lead Co.'s Works, Mansfield Valley, Pa. 1876–78, Assistant Supt. Orinoco Exploring and Mining Co., at their Gold Mines

in Venzuela. 1878-79, Supt. of the same. 1879-81, Examining Mines in Colorado, Utah, Nevada and California, for New York Investors. 1881-85, Supt. St. Helena Gold Mines, Sonora, Mexico. 1885, opened office in New York, as Consulting Engineer, and since then has been engaged as Consulting Mining and Metallurgical Engineer in Peru, Republic of Colombia, Dutch and British Guiana, Mexico, British Columbia, Ontario, New Brunswick and the United States. 1895, Consulting Mining and Engineer and Genl. Mgr. Hudson River Day Line. Member of firm Olcott, Fearn & Peele, Consulting Mining Engineers.

ORMSBEE, JAMES JACKSON, E.M., ... 1886.

Superintendent Tenn. Coal, Iron and Railway Co., Tracy City, Tenn.

1886-91, Mining Engineer of Tracy City Division of Tennessee Coal, Iron and Railroad Co. 1891-82, Superintendent, Thomas Coal Mines, of Tennessee Coal, Iron and Railroad Co., Whitwell, Tenn. 1892-94, Engineer and Superintendent Sequachee Valley Coal and Coke Co. 1894, Superintendent Poplar Creek Div. Tenn. Coal, Iron Railroal Co.

OSTERBERG, MAX., E.E., A.M., ... 1894.

27 Thames Street, and 113 East Fifty-sixth Street, New York City.

Summer '84, after graduation : Editor of the *Proceedings* of the Chicago Electrical Congress. Practical shopwork in a dynamo factory. October 1st, Appointed Associate Editor of *Electrical Power*. During season '94-'95 Instructor of Electrical Engineering at the National School of Electricity, at the Y. M. C. A. in New York City, and Stamford, Conn. Fall '94, Reëntered College to pursue post-graduate studies. June, '95, was appointed University Fellow in Mechanics. January, '96, author of " *Synopsis of Current Electrical Literature.*" Established as Consulting Engineer and Electrical Expert on September 1, '96.

OSTERHELD, THEODORE W., E.M., ... 1886.

Consulting Engineer, Apartado, No. 38c, Pueblo, Mexico.

Assistant Superintendent of Blast furnaces, P. S. Co. 1886-87. General Foundry Practice, Worthington P. Works, 1877-88. Owners of Foundry and General Iron Works, 1888-89. Vice-President Pendleton Mining Co., and Consulting Engineer, 1889, '90, '91, and general Consulting Engineer, Iron and Coal Specialty, and Metallurgist of Iron and Finished Manufacturing. Interval of 1890-91, of the months of December to May, Superintending Construction of Rolling Mill, Southwest Virginia. Specialty Coal and Iron of the Virginias. President of the Southern Reducing Co , Experts, Chemists and Mining Engineers. Locating Engineer C. & M. R. R., Cartagena, '91-92 ; Chief Engineer, C. & Z. R. R., '93-'94-'95, Coahuila, Mexico. '95 to present date, Consulting Engineer and Member of the Banking Firm, Rosst, Headen & Co., Pueblo, Mexico. Member and Consulting Engineer Banking and Exporting Firm Rosst, Headen & Co.

P.

PAGE, GEORGE STEPHEN, E.M., ... 1885.

Care Park Bros. & Co., Limited, and 6710 McPherson Street, Pittsburgh, Pa.

1885-'96, Assistant Chemist Edgar Thompson Steel Works. From July 1, 1886, to date, Manager of Steel Works with Park Bros. & Co., Ltd. Specialty. Manufacture of Open-Hearth and Crucible Steel.

PAGE, WILLIAM STEVENS, E.M., ... 1882.
Aqueduct Commission, Sing Sing, N. Y.

PAINTER, CHARLES ALBERT, E.M., ... 1884.
J. Painter & Sons, Pittsburgh, Pa., and 208 Western Avenue, Allegheny City, Pa.

PAINTER, GEORGE EDWARDS, PH.B., . . . 1883.
J. Painter & Sons Co., Pittsburgh, Pa., and 212 Western Avenue, Allegheny City, Pa.

PARKER, ANDREW MCCLEAN, E.M., . . . 1880.
Engineer and Superintendent Shanly, & Ryan, 26 Tompkins Street, New York, and 56 Jerome Street, Brooklyn, N. Y.
First Assistant Engineer, Department of Docks, New York City. Engr. and Supt. of Construction N. Y. Anchorage New East River Bridge.

PARKER, HERSCHEL CLIFFORD, PH.B., . . . 1890.
Department of Physics, Columbia University, New York City, and 21 Ft. Green Place, Brooklyn, N. Y.
1890–91, Fellow in Physics. 1891–93, Assistant in Physics. 1893–99, Tutor in Physics, Instructor in Electrical Measurements.

PARKER, RICHARD ALEXANDER, C.E., E.M., . . 1878.
Consulting Mining Engineer, Crocker Building, San Francisco, California.
1878–79, Assistant Superintendent, Montezuma Silver Mining Co., Mentezuma, Colo. 1880–81, Surveyor at Georgetown. 1881–82, Chief Draughtsman, Mexican Natl. Cons. Co., Laredo, Texas. 1883–84, Examining Mines in Colorado, Utah and Idaho mainly. 1885–86, Superintendent, Atlanta Hill Gold Co. Ala. Superintendent of the Big Lode (Gold) Co., Atlanta, Alturas Co., Idaho. 1887, Resident Manager and Agent for Samson Iron Co., Imperial Iron Co., and Barasa Iron Co. 1896, General Manager Simmer & Jack, Prop. Mines Ltd., Johannesburg, South Africa. 1897 to date, Consulting Engineer and General Manager California Exploration, Ltd.

PARKS, JOHN RANDOLPH, E.M., ... 1880.
Helena, Mont.
Consulting Mining Engineer.

PARRAGA CHARLES FREDERICK, C.E. (Life Member), 1883.
58 William Street, and 145 W. Ninety-seventh Street, New York City.
1883–85, Inspector of Construction of Bridges and Railroad Material in Europe. 1884–86, Railroad Engineer in Colombia, S. A. 1888 to date, General Expert Business. 1691, Delegated from Columbia to the Inter-Continental Railway Commission at Washington, D. C.

PARROT, EDWARD MONROE, E.M., ... 1870.
Ontario, Wayne County, N. Y.

PARSONS, HENRY, C.E., ... 1888.
Secretary and Treasurer, So. Ca. & G. R. R., 15 Broad Street and 1033 Madison Avenue, New York City.

PARSONS, WILLIAM BARCLAY, A.B., C.E., . . 1882.
22 William Street, and 51 East Fifty-third Street, New York City.
Previous to graduation served as Assistant Engineer Arnot and Pine Creek Railroad and Blossburg Coal Mine. After graduation entered Maintenance of Way Department of the New York, Lake Erie and Western Railroad. Resigned in 1885 and commenced practice as Consulting Engineer, New York, as such have had charge of much heavy engineering construction. At present Chief Engineer Rapid Transit Commission, New York City.

PATTBERG, OTTO FREDK., E.M., ... 1898.
Chicago and Aurora Smelting and Refining Co., and 73 North Fourth Street, Aurora, Ills.
1898, Asst. Aurora Works, Chicago and Aurora Smelting and Refining Co.

PAYNE, CLARENCE QUINTARD, ... 1882.
President Payne Separator Co., 98 John Street, New York City and Stamford, Conn.

PECK, STAUNTON BLOODGOOD, C.E., E.M., . . 1886.
Link Belt Machinery Co., Thirty-ninth Street and Stewart Avenue, Chicago, Ill., and 111 East Thirty-fourth Street, New York City.
One and a half years Mechanical Engineer, Burr & Dodge, Philadelphia. Two years Assistant Chief Engineer Link Belt Engineering Company, Philadelphia. Since 1888, Assistant Chief Engineer Dodge Coal Storage Company. Since 1890 and at present, Chief Engineer Link Belt Machinery Company, Chicago. Specialty, handling materials in bulk or package and power transmissions.

PEELE, ROBERT, E.M., ... 1883.
"The Monterey," One Hundred and Fourteenth Street, and Morningside Park, New York City.
1883, Assayer, Designolle Reduction Works, Charlotte, North Carolina. 1883–84, Assayer and Assistant Superintendent Silver King Mining and Milling Co., Montezuma, Colorado. 1884–86, Foreman, Dry-crushing and Amalgamating Silver-mill, Silver King Mining Co., Pinal, Arizona. 1886, went to England to examine systems of Sewage disposal used in inland towns. 1887, Professional work as assistant, in New York and Arizona. 1888, Examining gold-mines in Republic of Colombia, S. A. Superintendent Mudsill Mining Co., Ltd., Fairplay, Colorado. Examinations and Ore-testing on Copper and Tin Properties, New Mexico and North Carolina. 1889, Examining Gold placers, Dutch Guiana, South America. 1889-90, Superintendent Oregon Gold-mining Co., Cornucopla, Oregon. 1890–92, Examining Silver-, Tin-, and Gold-mines, in Peru, Bolivia, and Republic of Colombia, S. A., for the Peruvian Exploration Syndicate, Ltd., London, and Lima, Peru. 1892, Adjunct Professor of Mining, Columbia University.

PELLEW, CHARLES ERNST, E.M., ... 1884.
Columbia University, West 116th Street, and 51 East Fifty-fourth Street, New York City.

1884–85, studied chemistry at Lehigh University and Bethlehem Steel Works. 1885–87, studied chemistry, physics, microscopy and bacteria at School of Mines and at College Physicians and Surgeons. Private Assistant to Professor Chandler. 1887 to 1897, Instructor and, later, Demonstrator in Physics and Chemistry at College Physicians and Surgeons. 1897, Adjunct Professor of General Chemistry, Columbia University, with special charge over Laboratory of Industrial Chemistry. Also in general chemical practice with Professor Chandler.

PEUGNET, CHARLES PAUL ERNST, C.E., A.M., . . 1895.
Care of Nicaragua Canal Commission, 734 Fifteenth Street, Washington, D. C., and 231 West Forty-fifth Street, New York City, N. Y.

October, 1895, to June, 1896, Post-gruduate work at Columbia University, principally in Hydraulic and Electrical Engineering. February to December, 1897, with Metropolitan Street Railway Co. of the city of New York—on Construction Corps in charge of Principal Assistant Engineer. December, 1897, to June, 1898, and from October, 1898, to present date, with U. S. Nicaragua Canal Commission—on Survey in Nicaragua and subsequent office work at Washington, D. C.

PENNINGTON, JOSEPH POPE, A.M. (Associate), . . 1868.
Morristown, N. J.

1881–83, Assistant Engineer E. T. V. & G. R. R. 1883–84, Engineer Tombstone Mill and Mining Co. 1885–93, railroad construction with general contractors. Assistant Secretary, Louisville, St. Louis and Texas Railway. Resigned August, 1893. Previous responsibilities as actuary in connection with life insurance interests.

PERRINE, GEORGE, C.E., ... 1894.
22 William Street and 820 West End Avenue, New York City, N. Y.

With Chief Engineer Rapid Transit Commission, New York City, since graduating.

PERKINS, THOMAS SLADE, PH.B., ... 1888.
Ninth Street and Gowanus Canal, South Brooklyn, and 39 Garden Place, Brooklyn, N. Y.

1889 to date, New York Tartar Company.

PERKINS, SEYMOUR, C.E., . . , . . . 1897.
42 West Forty-sixth Street, New York City.

PIERCE, FREDERICK EMERY, C.E., ... 1892.
Dept. of City Works, Room 49 Municipal Building, 194 Joralemon Street, Brooklyn, N. Y.

1892, Employé in Bessemer Mill, Maryland Steel Co., Sparrow's Pt., Maryland. 1893, Draughtsman, New Jersey Steel and Iron Co., Cooper, Hewitt & Co., New York City. Trenton, N. J. 1895, P. R. R. Engineer in Corps of Principal Assistant Engineer at Jersey City. 1895–7, Engineer-draughtsman, Wallabout Improvement, Dept. of City Works, Brooklyn.

PIEZ, CHARLES, E.M., ... 1889.
Chief Engineer Dink Belt Engineering Co., Nicetown, and 3124 North Broad Street, Philadelphia, Pa.

1889-91, Draughtsman with the L. B. E. Co. 1891-92, Assistant Chief Engineer L. B. E. Co. Since 1892, Chief Engineer of the L. B. E. Co., and the Dodge Coal Storage Company.

PINKHAM, HERBERT, C.E., ... 1895.
Assistant Superintendent J. J. Astor Estate, Ferncliff, Rhinebeck, N. Y., and 176 West Eighty-first Street, New York City.

1895 to 1897, in Engineer's Corps, Principal Assistant Engineer, U. R. Rds. of N. J. Div., Penn. R. R. December, 1897, to date, Assistant Superintendent J. J. Astor estate, Rhinebeck, N. Y.

PISTOR, WILLIAM, E.M., ... 1868.
Architect. 68 Broad Street, New York City.

PITKIN, LUCIUS, A.B., PH.B., ... 1881.
138 Pearl Street, New York City.

1880-85, Chemist to Laurel Hill Chemical Works, of Nichols Chemical Company, heavy Chemicals, especially sulphuric acid. 1885 to date, Analytical and consulting Chemist, at above address. Specialty in consulting. Manufacturers of acids and heavy chemicals, treatment of pyrites and copper smelting. Analytical work in general but special experience in argentiferous and auriferous copper ores and products. Microscopical ond experimental investigations.

POLLEDO, YSIDOSO YGNACIO, E.M., ... 1885.
Address unknown.

1885, Assistant Engineer, Survey for Water Works for City of Santiago de Cuba. 1886-89, Assistant Engineer and Principal Assistant Engineer in charge of track and structures, Cárdenas and Júsuro R. R., Cárdenas. 1889-90, Manager of Santa Barbara Sugar Plantations, Baró. 1894-95, General Manager Cárdenas Sugar Refining Co., Cárdenas.

PORTER, H. HOBART, JR., E.M., ... 1886.
Sanderson & Porter, Engineers and Contractors, 31 Nassau Street, New York City, and Lawrence, L. I., N. Y.

1886-87, Fellow in Geology, School of Mines, Columbia University. 1887-88, Surveyor and Assayer Mexican Ore Company, Sierra Mojada, Mexico. 1888-89, Assistant Mining Engineer, Batopilas Mining Company; Batopilas, Mexico. 1889-90, Surveyor and Assayer, Duquesne Mining Co.; Assistant Superintendent Ray & Poorman mine examinations, same company; Assistant Superintendent Sierra County, Arizona, same company. 1890-91, Engineer with C. W. Hunt Company. 1891 to date, Westinghouse Electric and Mfg. Co. Member of firm of Sanderson & Porter, Engineers and Contractors Electric Rys, Power Transmission and Lighting.

PORTER, JOHN BONSALL, E.M., PH.D., . . . 1882.
Professor of Mining and Metallurgy, McGill University, Montreal, Canada.

1882-84, Field work on Economic Geology (coal and iron) of Alabama, Georgia

and Tennessee. 1884–88, Instructor and Lecturer on Mining and Mechanical Engineering and Metallurgy in University of Cincinnati and Expert in Metals and Ores for Q. & C. Ry. 1888-92, Engineer Maintenance of Way, C. H. & D. Ry. System. 1893–96, Chief Engineer and Superintendent C. & W. Ry and Engineer P. & G. Co., Cincinnati, O. 1896, Professor of Mining and Metallurgy, McGill University, Montreal.

POST, ABRAM SKIDMORE, C.E., ... 1884.
29 Liberty Street, New York City.

POWELL, FREDERICK, A.B., E.M., ... 1883.
Consulting Engineer, Hammond Manufacturing Co., 69 First Street, Portland, Oregon.

1883–84, Mechanical Draughtsman and Engineer. 1885, Assayer at Duluth, Minn. Examination and Reports on Mineral Deposits in northeastern Minnesota and Canada, Assayer and Manager for Sentinel Gold Mining Co. of Minneapolis and Colorado. 1886 to 1888, Superintendent and Manager in Colorado for Denbigh Mining Co., of New York. 1888–92, Miscellaneous Surveying. 1893, Engineer for Charlotte Mineral and Mining Co., Charlotte, N. C. Examining and Reporting on Mines in North Carolina. June, 1894 to 1896, Mining Engineer, Charlotte, N. C.

POWERS, LEWIS, J., JR., E.M., ... 1884.
Connecticut River Paper Company, Holyoke and Springfield, Massachusetts.

1885, Superintendent Vermont Construction Company, St. Albans, Vt. 1886, Superintendent Standard Pulp Company, Sprinfield, Mass. 1887–88, Assistant Superintendent Union Paper Manufacturing Company, Holyoke, Mass. 1888 to date, Agent Connecticut River Paper Company, Holyoke, Mass.

PRESTON, WILLIAM EVANS, C.E., ... 1889.
Foot E. Ninety-second Street, and 980 Trinity Avenue, New York City.

1889 to date, submarine blasting and dredging for U.S. Harbor work, with grapple, divers and centrifugal pumps.

PRINCE, JOHN L., E.E., ... 1894.
Edison Electric Illuminating Co., of New York, 53 Dunane Street, New York City, and 868 Flatbush Avenue, Brooklyn, N. Y.

Summer of 1894, Electric Light Station of the Flatbush Gas Co., Flatbush, L. I. Fall of 1894, with the General Electric Co. installing plant for the Bridgeport Traction Co., Bridgeport, Conn. Spring of 1895, in the Department of Public Works, Brooklyn, N. Y. October, 1895, to date, Inspection Department of the Edison Electric Illuminating Co., or N. J.

PROSSER, HERMAN A., E.M., E.E., ... 1896.
B. C. S. & R. Co., Keyser Building, Baltimore, Md.

Summer of 1896, Assistant Engineer Northwestern Mining and Exchange Co., Pa. 1896-97, Electrical Engineering course at Columbia. June, 1897, to date, Electrician, Baltimore Electrolytic Refining Co., Baltimore, Md.

PROVOST, ANDREW J., JR., C.E., ... 1889.

Municipal Building, and 402 Washington Avenue, Brooklyn, N. Y.

1889 to 1894, Assistant Engineer in Sewage Construction, Department City Works, Brooklyn, N. Y. 1894-96, Engineer in charge Sewerage design, Dept. City Works, Brooklyn, New York. 1896-97, Secretary Brooklyn Engineers' Club, Consulting Engineer, Columbian Colliery Company.

PUTNAM, B. R., B.S., A.M., ... 1893.

Chemist, Montana Ore Purchasing Co., and 309 West Broadway, Butte, Mont., and 15 Quebec Street, Victoria.

Received degree of B. S. in Mechanical Engineering from the Rose Polytechnic Institute in 1892, and the degree of A.M., for work in Mining, Metallurgy, etc., from Columbia University in 1893. 1894-96, Assistant Chemist, South Works, Illinois Steel Co. 1896-97, Chemist for the Union Colliery Co., Victoria, B. C.

R.

RANDOLPH, JOHN COOPER F., A.B., A.E., EM., . 1869.

Consulting Mining Engineer, Mill Building, 15 Broad Street, New York City.

RANDOLPH, JAMES FITZ, B.S., E.M., . . . 1876.

64 Madison Avenue, Morristown, N. J.

RAYMOND, ROBERT MATTHEW, A.B., E.M., . . 1889.

Kalgoorie, West Australia.

1880-82, Assistant Sayer, State of Maine Assay Office, Portland, Me. 1882-86, Assayer and Assistant Superintendent, Haile Gold Mine, S. C. 1886-89, School of Mines. 1889-90, Assayer and afterwards Assistant Superintendent, Montana Smelting Co., Great Falls, Mont. 1891, Superintendent, The Diamond Mining Co., Neihart, Mont. 1894, General Manager Harquahala Gold Mining Co., Harquahala, Ariz. 1896-97, General Manager Harquahala Gold Mining Co., Ltd., Arizona and West Australia. General Manager Brownhill Proprietary Gold Mines, Ltd., and Representative Mines Selection Co., Ltd.

RECKHART, DANIEL WILLIAM, E.M., (Life Member), . 1884.

Proprietor Independent Assay Office, Box 88, El Paso, Texas.

RECKHART, GEORGE FREDERICK, C.E., . . . 1892.

Commonwealth Mining and Milling Co., Pearce, Cochie County, Arizona, and 500 W. Thirty-fifth Street, New York City.

Member of "Southwestern Mining Association" (Incorporated). Surveyor and Assayer for Cia Minera La Aventurea, Sabinal, Estado de Chihuahua, Mexico, since September, 1894. From February, 1894, to August, 1894, was on Engineering Staff on South Shore Railroad Co., Ltd., of Nova Scotia, Canada. 1896, Manager, The Furners & Lewis Co., Pachuca, Estado de Hidalgo, Mexico. Since September, 1896, with Commonwealth M. and M. Co., Pearce, Arizona.

REED, SILVANUS ALBERT, A. B., A. M., E. M. (Life Member), ... 1877.

Manager Tariff Association of New York (Fire Underwriters) 32 Nassau Street, New York City.

1878, Secretary to Assistant Commissioner General, Paris Exposition. 1879, Lectured on Chemistry. Reported on Mines in Colorado. 1880–81, Superintendent and part Proprietor, Sampling and Concentration Works in Colorado, and Reported on Mines there and in Idaho and in the South. 1886, consulting Practice in New York, Patent Expert work and on Dredging in New York Harbor. 1886–91, Superintendent Inspection Department of Fire Insurance Co. (Commonwealth of New York). 1893, Expert for New Insurance Rating, Mercantile Section of Boston. May, 1893, appointed Manager Western Factory Insurance Association. Special Agent Western Department of Continental Insurance Co. 1894, Manager Tariff Association Fire Underwriters, New York City.

REES, JOHN KROM, PH. D., A.B., A.M., E.M., (Life Member), ... 1875.

Professor of Astronomy and Director of Observatory, Room 610 Physics Building, Columbia University, and 1 West Seventy-second Street, New York City.

A.M., 1875. E.M., 1875. Assistant in Mathematics, School of Mines, 1873–76. Professor of Mathematics and Astronomy, Washington University, St. Louis, Mo. 1876–81, Director of the Observatory, Columbia University, from 1881. Instructor in Geodesy and Practical Astronomy, Columbia University, 1881–82. Professor of Astronomy, from 1892. Chairman Board of Editors, SCHOOL OF MINES QUARTERLY, 1883-90. Vice-President New York Mathematical Society, 1891. Chairman of section on Astronomy and Physics of New York Academy of Sciences. 1891–94, Secretary of American Metrological Society, 1882–97. Fellow of Royal Astronomical Society of London, from 1892. Member of the Astronomische Gesellschaft, from 1893. President of New York Academy of Sciences, 1894–96. Secretary of University Council, 1892-98.

RENAULT, GEORGE, C.E., ... 1883.

122 E. Nineteenth Street, New York City.

RHODES, FRANCIS BELL FORSYTHE, E.M., . . . 1874.

National S. & R. Co., South Chicago, Ill., and Quebec, Canada.

May, 1875, to December, 1876. Surveying Corps, Coxe Bros., Drifton, Pa. January, 1877, to May, 1878, Assistant Superintendent, South American Mining Co., Venezuela, November, 1878, to June, 1879, Working at Lead Mine, Canada. October, 1879, to April, 1880, Laborer, Ontario Mill, Park City, Utah. April, 1880, to July, 1881, Assistant Superintendent, Mingo Furnace Co , Utah. August, 1881, to January, 1882, Assistant Superintendent, St. Helena Mine, Sonora, Mexico. January, 1882, to April, 1883, Assistant Superintendent, Tombstone, M. and M. Co., Arizona. May, 1883, to December, 1883, Superintendent Ramsham Smelting Furnace, Idaho. January, 1884, to May, 1885, Assistant Superintendent, Mingo Furnace Co., Utah. June, 1885, to December, 1885, Foreman of Blast Furnace Department, Kansas City S. and R. Co. October, 1886, to December, 1889, Superintendent Chicago Works, Chicago and Aurora S. and R. Co. January, 1890, to date, Superintendent National S. and R. Co., South Chicago.

RHODES, ROBERT DUNN, E.M., ... 1879.

Superintendent Philadelphia Smelting & Refining Co., Pueblo, Colo., and Quebec, Canada.

1889–80, Foreman, Germania Smelting Co., Salt Lake City. 1880–82, Night Foreman Ontario Silver Mining Co., Park City, Utah. 1882–83, Superintendent Tombstone, M. and M. Co. Reduction Works, Charleston. 1883–84, Mill Foreman, St. Helena Gold and Silver Mine, Sonora. 1884–82, Assistant Superintendent, Billings Smelter, New Mexico. 1885–86, Assistant Superintendent Viola M. and S. Co., Idaho. 1887–88, Assistant Superintendent, Anglo-Mexican Mining Co., Yedras, Mexico. 1889–91, General Superintendent, Duquesne M. and R. Co., and Sierra County, Arizona. 1891–92, Engineer Fraser and Chalmers, City of Mexico. 1892, Superintendent. 1886, Arkansas Valley Smelting Works, Leadville, Col. 1897 to date, Supt. Phila. Smelting and Refining Co., Pueblo, Col.

RICE, GEORGE SAMUEL, JR., E.M., ... 1887.
936 The Rookery, Chicago, Ill., and 1426 Benson, Avenue, Evanston, Ill.

1887, Assistant Field Engineer Colorado & Utah Railway. 1888–89, Assistant Mining Engineer of Colorado Fuel Co. 1800–97, Mining Engineer of Whitebreast Fuel Co. 1897, with Whitebreast Fuel Co., Chicago, Ill.

RICH, JACOB MONROE, E.M., C.E. (Life Member), . 1883.
50 West Thirty-eighth Street, New York City.

Pursuing further studies since graduation.

RICKETTS, PIERRE DE PEYSTER, E.M., PH.D., . . 1871.
Professor of Analytical Chemistry and Assaying, Columbia University School of Mines, and 115 E. Seventy-ninth Street, New York City.

1868, Assistant General Chemistry, Columbia University. 1871–72, Assistant in Mineralogy and Metallurgy, School of Mines. 1872–75, Assistant in Assaying, School of Mines. 1875–86, Instructor in Assaying, School of Mines. 1886 to 1894, Professor of Assaying, School of Mines. Since graduation also engaged general Metallurgy, Chemical and Mining Engineer work.

RIEDERER, EMIL J., ... 1897.
Assistant in Chemistry, Assay Laboratory, Columbia University, New York City.

RIES, HEINRICH, PH.B., A.M., PH.D., . . . 1892.
Department of Economic Geology, Cornell University, Ithaca, N. Y.

Barnard Fellow in Columbia University. 1897 to 1898, Delegate from Columbia Universiiy and New York Acad. of Sci. to 1897 Geological Congress in St. Petersburg, Russia. Summer of 1897, engaged in a study of the important clay deposits of England, Germany, France, Belgium, Austria and Denmark. Fall and winter of 1897, engaged in study of physical properties of clay at the University in Berlin, Germany.

Summer of 1891 and 1892, on New York Geological Survey. October, 1892, to August 1, 1893, Assistant Director, New York Scientific Exhibit, at World's Fair. July 1, 1893, to July 1, 1895, Fellow in Mineralogy, Columbia University. Asst. Geologist, N. Y. Geol. Survey, summer of 1895. Lecturer in New York City Public Schools, 1895–1897. Judge of Clays, Cotton States and International Exposi-

tion, October, 1895. Clay Specialist, U. S. Geological Survey, 1895 to date. In connection with this work am engaged in a study of the clays of the various States, Summer of 1898 engaged in geological work in Alabama and New York State. 1898, Instructor in Economic Geology, Cornell University, Ithaca, N. Y. Am also engaged in a detailed investigation of the clays of Alabama and New York.

RODENBURG, CHAS., C.E., ... 1896.

American Diamond Rock Drill Co., 120 Liberty Street, and 428 W. Forty-fourth Street, New York City.

Summer 1896, Assistant at Summer School of Geodesy, Columbia University. December, 1896, with J. L. Greenleaf, C.E., on Survey in Adirondacks. From January, 1897, to date, with the American Diamond Rock Drill Co., and also with the Driggs, Seabury Gun and Ammunition Co.

ROESER, FREDERICK, B.S., E.M., ... 1884.

Care of Oceana Consolidated Co., P. O. Box 1542, Johannesburg, S. A. R.

ROGERS, CHARLES E., C.E., ... 1897.

Engineering Department, U. S. A., Key West, Fla.

ROGERS, OSCAR LEGARE, PH. B. (Arch), . . . 1889.

125 W. Eighty-fifth Street, New York City.

1889–92, in Europe. 1893, Architect. 1894, in Europe.

ROLKER, CHARLES M., E.M. (Life Member), . . 1875.

6 Drapers' Gardens, London, E. C., England.

1868–70, at Royal School of Mines, Clausthal, Germany. 1871–72, Working practically in Iron Mines of Hibernia and Mt. Pleasant, N. J., Wisconsin Lead Mines and Iron Mines of Lake Superior. 1872–75, at School of Mines, Columbia College. 1876, Assayer at Allouez Copper-dressing Works, Lake Superior. 1877, Mining Engineer to the Mariposa Land and Mining Co., Mariposa Co., Cal. (Gold). 1878, Superintendent, Brooklyn Company, Washoe Co., Nevada (Base Metal). 1879, Superintendent Stormont Silver Co., Silver Reef (Silver). 1880–82, General Manager Chrysolite S. Mfg. Co., Leadville, Col. (Lead Carbonates). Since then to date, in General Consulting Practice as Mining Engineer and Metallurgist, Examining Mines, Mills and Placers in the United States, Old Mexico, Central America, South America and East Indies. Specialty, Precious and Base Metals other than Iron. 1891–92, Consulting Engineer to the British South African Company in its sphere south of Zambesi. 1894, Practicing, Consulting Mining Engineer. 1895–96, Manager Mining and Financial Trust Synd., London.

ROS, JUAN PABLO, B.A. (Havana University), E.M. . 1898.

Vives 48, Cienfuegos, Cuba.

ROSENTHAL, ALBERT, C.E., ... 1892.

221 Coulter Street, Germantown, Philadelphia, Pa.

ROWLAND, CHARLES BRADLEY, C.E., ... 1884.

Continental Iron Works, Greenpoint, Brooklyn, N. Y., and 329 Madison Avenue, New York City.

ROWLAND, GEORGE, C.E., ... 1887.
Continental Iron Works, Greenpoint, Brooklyn, N. Y., and 329 Madison Avenue, New York City.

RUPP, PHILIP, PH.B., M.D., ... 1884.
334 E. Seventeenth Street, New York City.
1884-87, Student of Medicine, College of Physicians and Surgeons, N. Y. 1887-88, House Physician and House Surgeon, St. Francis Hospital, N. Y. 1888 to date, Practicing Physician.

RUTHERFURD, F. M., E.M., ... 1879.
46 E. Sixty-fourth Street, New York City.
Engineer M. of W. R. and D. R. R. till 1894. 1895 to date, 2d Deputy Superintendent Dept. of Buildings, New York City.

RUTTMANN, FERDINAND, E.M., ... 1880.
Mining Engineer, 45 Broadway and 547 W. 147th Street, New York City.

RYON, AUGUSTUS MEADER, E.M., ... 1886.
97 Main Street, Flushing, N. Y.
1886-87, Assistant Engineer on New London Water Works. Assistant in Metallurgy, School of Mines, Columbia University. 1887-88, Assistant to F. N. Owen, Civil and Sanitary Engineer, New York City. 1888-91, Professor of Engineering and Mining, School of Mines, College of Montana, Deer Lodge, Mont. 1892 to 1895, President and Professor of Engineering, Montana College of Agricultural and Mechanical Arts, Bozeman, Montana. 1894, Irrigation Engineering for Agricultural Experiment Station. 1895, Professor of Engineering, College of Agr. and Mech. Arts, Bozeman, Montana.

S.

SAGE, EDWARD EUGENE, C.E. (Life Member), . . 1877.
United States Assay Office, 30 Wall Street, New York City, and 33 Fairview Avenue, Orange, N. J.
I have been connected with this office since February, 1878, and have consequently no outside experience except electricity, being President of the Essex County Electric Co., of Orange, N. J., and in Analytical Chemistry.

SANDS, FERDINAND, A.B., PH.B., ... 1882.
Drugs and Assaying Supplies, Box 1172, Butte, Mont.

SAUNDERS, GEO. CROSBY, B.S., C.E., ... 1898.
513 W. 142nd Street, New York City.
Assistant in Summer School of Surveying, season 1898.

SCHELL, R. MONTGOMERY, B.S.. . . . . 1895.
156 Fifth Avenue, and San Remo, W. Seventy-fourth Street, New York City.
1895, with Cady Berg & See, Architects. 1896, with George Keister, Architect. 1897, with Clinton & Russell, Architects. 1898 to date, Architect, 156 Fifth avenue. 1896-97-98, Instructor in Archt. Drawing, West Side Rranch Y. M. C. A-

SCHERMERHORN, FREDERICK AGUSTUS, E.M. (Life Member), 1868.
41 Liberty Street and 101 University Place, New York City.

SCHIEFFELIN, WILLIAM JAY, PH.B., PH.D. (Munich), 1887.
Schieffelin & Co., 170 William Street and 35 W. Fifty-seventh Street, New York City.

SCHNEIDER, ALBERT FRANCIS, E.M., C.E. (Life Member), 1876.
Perth Amboy, N. J.

1876–77, in Europe visiting Smelting and Dressing Works. 1878. Chemist and Assayer Germania S. and R. Co., Salt Lake City, Utah. 1879, Foreman. Assistant and Superintendent Germania S. and R. Co., Salt Lake City. 1880–83, Superintendent Germania S. and R. Co., Salt Lake City, Utah. 1883–85, Superintendent G. Billing Smelting Works, Socorro, N. M. 1885–87, Superintendent Kansas City S. and R. Co., Argentine, Kansas. 1887, Connected with the Rio Grande S. Co., Socorro, N. M. 1887 to 1893, General Manager St. Louis S. and R. Co., St. Louis, Mo. Superintendent Great National Smelting Co., Monterey, Mexico, 1895.

SCHROEDER, J. LANGDON, C.E., ... 1889.
Member of the firm of Parish & Schroeder, Architects, 3 W. Twenty-ninth Street and 50 W. Eleventh Street, New York City.

July, 1890, to January, 1894, with Renwick, Aspenwall & Renwick, New York City, Architectural Draughtsman.

SCHUMANN, CHARLES HENRY, C.E., ... 1888.
Small & Schumann, 256 Broadway and 51 E. Ninety-ninth Street, New York City.

1883, to May, 1890, Assistant Engineer Chesapeake and Ohio Railway Co., Cincinnati. charge of Real Estate, Right of way and Track and Construction Work. May to August, 1890, Assistant Engineer to H. Alber, C. E., Birmingham, Ala., General Engineering. August, 1889, to March, 1891, Assistant Engineer, Chesapeake and Ohio Railway Co., charge of subdivision of Town of West Clifton Eorge, Va., and Right of Way on line of road. 1892–93, Assistant Engineer Long Island, R. R., and Engineer for Ferris & Richards, Contractors for Railroads and Waterworks, at 90 Hudson street, Jersey City, N. J. 1893–94, with James R. Croes, C. E., Waterworks Supply and Sewage, 1894. Private practice as Small & Schumann, Arichitects and Civil Engineers.

SEARLE, CHARLES D., C.E., ... 1896.
32 W. 126th Street, New York City.

SELDNER, RUDOLPH, PH.B., B.S., ... 1894.
217 Jefferson Avenue, Brooklyn, N. Y.

Instructor in Science, Adelphi Academy, 1894 to 1897. Chemist Orangeburgh Chemical Works, 1897–98.

SELF, E. D., E.M., ... 1894.
Box 550, Johannesburg, South Africa. and South Orange, N. J.

Received degree of Mechanical Engineer at the Stevens Institute of Technology in 1886. Engaged in Engineering and Construction work. Designing and pur-

chasing machinery for large mills in Australia and Mexico. Reports on transmission of power project for mining plant in Mexico. Examination of Mines in South America. Superintendent of mine in Guyana, South America. Received degree of Engineer of Mines from Columbia College in 1894. Assistant in Mining at Lake Superior for class in practical mining. Superintendent and Manager of the Sonora Copper Co., Sonora, Mexico. Received patent for System of ore concentration. Consulting Mechanical and Mining Engineer on deep level work, to an English Investment Co., and to several mining companies.

SESSINGHAUS, GUSTAVUS, E.M., ... 1898.
2401 North Twelfth Street, St. Louis, Mo.

SEWARD, JOHN, E.M., ... 1895.
97 Cedar Street, New York City, and 417 Main Street, Grange, New Jersey.

SHARE, WILLIAM WALDEMAR, PH.B., PH.D., . . 1881.
Adelphi College, and 331 McDonough Street, Brooklyn, N. Y.

1881, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1881-88, Assistant Physic., Columbia College. 1888, Consulting Electrician, Department of Public Parks, Brooklyn, N. Y. 1889 to date, Professor of Chemistry, Adelphi Academy, Brooklyn, N. Y.

SHATTUCK, L.R., B.S., C.E., ... 1895.
Care of John Monhs & Son, 130 Water Street, New York City, and 184 Eighth Avenue, Brooklyn, N. Y.

1895, Draughting and Field work with the Ramapo Water Co. 1896-97, Engineer Inspector in the Department of Public Works, of New York City. 1898 to date, Assistant Superintendent of Construction and Sinking of Caissons for New Cincinnati Water Works at California, Ohio.

SHERMAN, FRANK DEMPSTER, PH.B., ... 1884.
Adjunct Professor of Architecture, Columbia University, New York City, 312 South Broadway, Yonkers, N. Y.

SHERMAN, G. F., C.E., ... 1894.
Grass Valley Nevada Co., Cal.

SHERMAN, HENRY C., A.M., PH.D., ... 1897.
Wesleyan University, and Drawer 74 A, Middletown, Conn.

Summer of 1893, Assistant Dairy Chemist, World's Fair, Chicago. 1893-94, Assistant in Chemistry, Maryland Agricultural College. 1894-95, First Assistant Chemist. 1895-97, Fellow in Chemistry, Columbia University. 1897-98, Assistant in Chemistry, Columbia University. 1898 to date, Assistant in Nutrition Investigations United States Department of Agriculture.

SHRIVER, HENRY TOWER, PH.B., ... 1888.
T. Shriver & Co., 633 E. Fifty-sixth Street, and 686 Park Avenue, New York City.

In Iron Foundry and Works, as above, since Graduation.

SIMONDS, FRANCIS MAY, E.M., PH.D., . . . 1887.
Member of Firm Simonds & Wainwright, 20 Platt Street, New York City.

1887-89, Working for Degree of Ph. D., and Assistant in Assaying at School of Mines. 1889-92, Assistant in Assaying at School of Mines and Chemist to Messrs. Ricketts & Banks. 1892-93, Lecturer in Assaying and Chemist as above. 1893-94, with Sterling Supply Co., Manufacturing Street Railway Supplies. 1894-95, opened a Laboratory at No. 30 Platt Street, N. Y., for Experimental Work in the treatment of Ores and Chemical Products. 1895, Associated with me in partnership, Mr. T. H. Wainwright, Class 1882, forming firm of Simonds & Wainwright, Chemical and Mining Engineers and Analysts.

SINGER, GEORGE, JR., E.M., ... 1880.
111 Fourth Avenue, Pittsburg, Pa.

SINGER, GEORGE HARTON, E.M., ... 1880.
Singer, Nimick & Co., Incorporated, Pittsburg, Pa.

SKINNER, ELMER, C.E., ... 1891.
227 Cumberland Street, Brooklyn, N. Y.

SLACK, CHARLES GODDARD, E.M., ... 1884.
328 Fourth Street, Marietta, Ohio.

SLADE, RICHMOND EDWARD, PH.B., ... 1887.
White Plains, N. Y.

1887, Assistant Superintendent United Gas Improvement Co., Yonkers, N. Y., Plants. 1888, Superintendent Gas Department, Ashville (N. C.) Light and Power Co. 1888, Superintendent Gas and Electric Plants, Citizen's Gas Light Co., Jackson, Tenn. December, 1889, to date, Secretary, Superintendent and Trustee Citizens' Gas and Electric Co., White Plains, N. Y. 1896, Secretary and Superintendent and Trustee Citizens' Gas and Electric Co., Secretary and Director N. Y.. Elmsford and White Plains Ry. Co., and Manager Consolidated Gas and Electric Light Co., of Westchester County, Port Chester N. Y.

SMITH, AUGUSTUS, A.B., C.E., ... 1889.
29 Cortlandt Street and 460 W. Forty-fourth Street, New York City.

Summer of 1896, Land Surveying (in charge of party). July to November, 1889, Draughtsman, Link Belt Engineer Co., Nicetown, Phila. November, 1889-91, Chief Draughtsman New York Office Link Belt Engineering Co. 1891-92, out of professional work. 1892, Salesman and Engineer as above. 1893 to date, private practice as Engineer and Contractor.

SMITH, FRANK MARSHALL, E.M., ... 1889.
Superintendent United Smelting and Refining Co., Smelter P. O., Great Falls, Mont.

1889-90, on the United States Geological Survey, engaged in hydrographic work on the Irrigation Survey and triangulation of the Topographic Survey in Idaho and Oregon. 1891, Assayer Colorado Smelting Co., Pueblo Col. October, 1892-93, Assistant Superintendent. 1893 to date, Supt. United Smelting and Refining Co., Smelter, Mont. Jan. 1st, 1898, appointed Manager United Smelting & Refining Co., Great Falls Works.

SMITH, FRANCIS PITT, PH.B., ... 1888.
College of Physicians and Surgeons, Fifty-ninth Street and Tenth Avenue, New York City, and 77 Woodland Avenue, New Rochelle, N. Y.

Analytical Chemist in Leather trade, 1888-89. Superintendent Chemical, Works, Wm. H. Swift & Co., East Boston, Mass., 1889-90. Consulting Chemist, Deming & Logan, 58 William Street, 1890. Assistant Chemist, New York City Health Department, 42 Bleaker Street, 1890-91. Consolidated Gas Company, New York City, 1891-92. Chemist United States Navy Department, Bureau of Supplies and Accounts, and Editor Anthony's Photographic Bulletin, 1892-95. Harrison Brothers & Co., Philadelphia, Pa., 1885-96. Superintendent Eidoloscope Co., 1896-97. Tutor in General Chemistry, Columbia University, 1897

SMITH, LENOX, A.B., A.M., E.M. (Life Member), . 1868.
47 Cedar Street, New York City.

SMITH, WILSON, FITCH, C.E., ... 1894.
22 William Street; *for mail*, 36 W. Thirty-sixth Street, New York City.

June to Oct., 1894, Assistant Instructor Summer School of Surveying, School of Mines, Columbia University. Oct., 1894-96, Engineering Department, New York Central and Hudson River R. R., as Rodman and Assistant Engineer, 1896, with R. W. Hildreth & Co., Civil Engineers. Jan., 1897, to date, with Wm. Barclay Parsons, New York City.

SMITH, WILLIAM ALLEN, E.M., ... 1868.
52 Wall Street, 102 E. Fifty-seventh, New York City.

SMITH, WILLIAM ALLEN, JR., E.M., ... 1898.
102 E. Fifty-seventh Street, New York City.

SMYTH, CHARLES HENRY, JR., PH.B., PH.D., . . 1888.
Professor of Geology and Mineralogy, Hamilton College, Clinton, N. Y.

1888-89, Chemist Franklin Iron Mfg. Co. 1889-90, Geological Field Work in New York, Alabama, Georgia and Tennessee. June, 1890, received Degree of Doctor of Philosophy from Columbia University. 1889-91, studied Petrography and Minerology with Prof. Rosenbusch at the University of Heidelberg. 1891, appointed Professor of Geology and Mineralogy in Hamilton College. Asst. on N. Y. Geol. Survey, 1893-95. 1897, appointed by the State Geologist to take charge of the Mapping of the Western half or the Adirondack Region. Interested chiefly in Petrographic and Chemical Geology and in Mineralogy.

SNOOK, THOMAS EDWARD, E.M., ... 1884.
Architect, 261 Broadway, New York City.

1884-87, Superintendent Construction for John B. Snook, Architect. 1887 to date, Member of the firm of and Chief Engineer for John B. Snook & Son, Architects.

SOUTHARD, GEORGE CARROLL, C.E., ... 1892.
111 Montague Street, Brooklyn, N. Y.

June, 1892, to March, 1893, Equity Gas Works Construction Co., Brooklyn, E. D. March, 1893, to January, 1894, with Heine Safety Boiler Co. January, 1893, to August, 1895, with Hecker-Jones-Jewell Milling Co. August, 1895, to July, 1897, with Southern Pine Co., of Ga. 1897, with Department Public Works, New York City.

SPOONER, ALLEN NEWHALL, C.E., ... 1886.

Department of Docks, Pier A, North River, New York City, and 186 Carteret Avenue, Jersey City, N. J.

July, 1886, to August, 1887, Rodman and Draughtsman, Penn. R. R., Jersey City. August, 1887, to May, 1890, Hydrographer Department Docks, New York City. May, 1890-91, to present time, Assistant Engineer Department Docks, New York City. Specialty, Railroad Engineering, River, Submarine and Harbor Engineering.

STANTON, FRANK MCMILLAN, E.M., ... 1887.

Superintendent Atlantic Mine, Houghton Co., Mich.

1887-88, Superintendent *pro tem.* Central Mine, Mich. 1888-89, Engineer Atlantic Mine, Mich. 1889 to date, Superintendent Atlantic Mine, Mich.

STAREK, EMIL, LL.B., LL.M., E.M., ... 1895.

Councillor at Law, 907 Chemical Building, St. Louis, Mo.

1885-87, Assistant in United States Geological Survey. 1887-92, Assistant Examiner United States Patent Office, Washington, D. C.

STAUNTON, WILLIAM FIELD, E.M. . . . . 1882.

Superintendent of the Congress Gold Co., Congress, Ariz.

1882, Assayer and Assistant Superintendent Vermont Copper Co., Ely, Vt. 1882, Assayer and Accountant Dunn Mt. Gold Mine, Salisbury, N. C. 1883, Assayer Ledoux & Ricketts, N. Y. 1883, Constructing Engineer, C. M. and R. Co., N. Y. 1883, Assistant to Manager of Mills and Smelting of T. M. and M. Co., Tombstone, Arizona. 1884, Consulting Engineer, N. Y. 1884, Mining Engineer for T. M. & M. Co., Tombstone, Arizona. 1890 to date, Superintendent Tombstone Mill and Milling Co., Tombstone, Ariz., and 1894, Superintendent Congress Gold Co., Congress, Ariz. Specialty, Gold and Silver Mining and Metallurgy.

STEARNS, THOMAS BEALE, E.M., ... 1881.

1720 California Street, Denver, Col.

STEWART, JOHN HENRY, C.E., ... 1895.

Department of Public Works, 150 Nassau Street, and 133 W. Eleventh Street, New York City.

STONE, GEORGE CAMERON, PH.B., PH.D., ... 1879.

New Jersey Zinc and Iron Company, Newark, N. J.

1879, Chemist, Booth and Edgar Sugar Refinery. 1879-82, Chemist with Potter & Riggs, St. Louis, Mo. 1882-91, with New Jersey Zinc and Iron Company, Newark, N. J., first as Chemist, since 1884 as Superintendent Blast-Furnaces. May, 1894, to date, Superintendent of Company.

STRUTHERS, JOSEPH, PH.B., PH.D., ... 1885.

Tutor in Metallurgy, Columbia University School of Mines, and 624 East 136th Street, New York City.

1885–88, Fellow in Mineralogy. 1888–90, Assistant in Mineralogy and Metallurgy. 1891 to date, Tutor in Metallurgy Columbia University, School of Mines. 1893–94, delivered the lectures in Metallurgy at the School of Mines, in place of Dr. Egleston. Summer of 1894, metallurgical trip in Europe. 1894–95, Special work upon pyrometers and calorimeters. Spring of 1896, delivered the lectures in Metallurgy at the School of Mines, in place of Dr. Egleston. Summer of 1896, in charge of the Summer School in Practical Metallurgy at Butte, Mont., and devoted three months to a metallurgical trip throughout the Western United States and British Columbia, visiting more than forty establishments. January 1, 1897, in charge of the lectures in Metallurgy at the School of Mines, in the absence of Dr. Egleston, resigned. Summer of 1897, in charge of Summer School in Practical Metallurgy at Chicago and Pittsburgh. Specialty, the measurements of high temperatures and the physical properties of slags.

STUART, WILLIAM HENRY, C.E., ... 1886.

36 W. Seventieth Street, New York City.

1886, on Railway Surveys in Minnesota and Wisconsin with C. B. & N. R. R. Co. 1887–89, Fellow in Engineering and Assistant in Summer School of Surveying, School of Mines, Columbia University. 1889–90, making surveys and superintending construction at the Hudson River State Hospital, Poughkeepsie, N. Y. 1890, on Surveys in the West Indies. 1893, in general practice.

SUTER, GEORGE AUGUSTUS, L.M., ... 1883.

G. A. Suter & Co., Engineers and Contractors, 112–114 Wooster Street, New York City, and New Rochelle, N. Y.

1884–92, Engineer, Baker, Smith & Co. 1892–97, with G. A. Suter & Co.

SUTRO, HARRY H., B.S., ... 1898.

Eagle Pencil Co., E. Fourteenth Street and 60 W. Forty-ninth Street, New York City.

SWAIN, ALFRED ERNEST, E.M., ... 1881.

Superintendent Trinidad Mining Co., Copala (via Mazatlan Sinaloa, Mexico), and 902 Prospect Street, Cleveland, O.

1881–84, railroad work in Mexico. 1885–88. City Engineer's Department, Kansas City, Mo., in charge of sewer work. 1889–91, mining work in Mexico. 1891, Superintendent San Buenaventura Mining Company, Santa Lucia, Sinaloa, Mexico, via Mazatlan and Panama. 1891–93, Superintendent of Trinidad Mining Company.

T.

TATLOCK, JAMES LLOYD, C.E., ... 1898.

Pelham, Manor, New York City.

Employed on construction of sewer outlet from village of New Rochell. Work includes pile driving, dredging, drilling and blasting rock bottom and driving of a tunnel four hundred feet long.

TAYLOR, JOSEPH B., E.M., ... 1888.

56 and 58 Pine Street, New York City, and 404 Seneca Street, Brooklyn, N. Y.

1888-90, Practical Shop Work. 1890-94, Draughtsman and Assistant Superintendent Columbian Iron Works, Brooklyn, N. Y. 1894 to date, General Practice, Mechanical Engineering.

TERHUNE, RICHARD HENRY, E.M., ... 1870.

562 S. Main Street, Salt Lake City, Utah.

1870, Assistant to late J. W. Foster, geology of coal fields, Indiana. 1871, Griswold Steel Works, draughting, bowling steel, etc. 1872-77, Joliet Steel Company, draughting, inspecting steel rails and exploration of Callaway County, Missouri for coal and iron. 1877-80, Superintendent and Assistant Superintendent Smelting Works, Utah. 1880-93, General Superintendent Hanauer Smelting Works, Utah. Specialty, construction and operation of lead Smelting works. Resigned above position September, 1893. 1894, Examining and Reporting on Mines and Works. October, 1896, reëlected to the position of Chief Engineer and General Superintendent of the Hanauer Smelting Works, Utah.

THACHER, ARTHUR, C.E., E.M., ... 1877.

President and General Manager Central Lead Company, 420 Roe Building and 4109 Washington Avenue, St. Louis, Mo.

1878-78, with Progreso Mining Company, Trimfo, Lower California, Mexico. 1879-83, Southern Arizona and Northern Mexico Mining and Milling. 1883-87, office in New York. Examining and reporting on mining and mills. 1887 to date, with Professor W. B. Potter, at St. Louis, Sampling and Testing Works and Washington University. Lecturing on Metallurgy. Testing ores, etc. Examining and reporting on mines and mills. Superintendent Central Lead Co.

THOMAS, FREDERICK MAYHEW, E.M., ... 1885.

Box 204, Skaneatilis, N. Y.

Leveller (Instrument man, etc.), on New York Canals, from September, 1887, to November, 1889 (position resigned). Transitman and leveller on preliminary railroad survey in Schoharie County in spring of 1890. Transitman and leveller on Syracuse Water Works during the winter of 1890-91. Assistant Engineer and later Principal Assistant to City Engineer Syracuse, N. Y., from August, 1891, to July 1, 1896. Position resigned on account of ill health. Out of active professional work on account of health until the fall of 1898.

THYNG, WILLIAM S., E.M., ... 1896.

Assistant Engineer, Tubular Dispatch Co., Tribune Building New York City, and *for mail* Roselle, N. J.

Employed on the Editorial staff of the Railroad Gazette of New York, from June 22, 1896, until November 20, 1897, and since November 20, 1897, to date has been Assistant Engineer of the Tubular Dispatch Company, Tribune Building, New York City.

TIBBALS, GEORGE ATWATER, C.E., ... 1883.

Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.

TIBBALS, SAMUEL GAYLORD, C.E., ... 1884.

Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.

1884 to date, as above.

TITCOMB, HAROLD A., E.M., ... 1898.
Hotel Van Nuys, Los Angeles, Cal.
1898, Sergeant, Company D, 201st Regt., N. Y. V. I.

TITUS, WARREN HARRIOTT, E.M., ... 1885.
Sanitary Engineer, Lincoln Building, 1 Union Square, New York City, N. Y., and Whitestone, N. Y.
1885–86, Post-graduate Course in Civil Engineering School of Mines and traveling in Europe. From 1886–92 in the Board of Health employed as follows: From October, 1886–87, Assistant Sanitary Engineer and Inspector of Plumbing. From 1887–88, Assistant Sanitary Engineer and Special Inspector of Plumbing, Drainage, Light and Ventilation. From 1888, to November, 1890, Assistant Sanitary Engineer and Special Inspector and Examiner of Plans for Plumbing, Drainage, Light and Ventilation. From November, 1890, to June, 1892, Assistant Chief Inspector of the Division of Plumbing, Drainage, Light and Ventilation. From December, 1891, to June, 1892, Acting Chief Inspector in charge of Division of Plumbing, Drainage, Light and Ventilation. From June, 1892, to October, 1895, Examiner of Plans for Plumbing, Drainage, Light and Ventilation in the Department of Buildings of New York City. 1885, Practicing as Sanitary Engineer, New York City. Specialties, Plans, Specifications and Superintendence of Water Supply and Sewage Disposal Plants for Country Residences and Institutions; Plumbing, Plans and Specifications for Large City Buildings, including Fire Service.

TOMPKINS, E. DE V., C.E., ... 1896.
732 West End Avenue, New York City, N. Y.
Assistant Instructor Summer School of Surveying, summer of 1892. One week after graduation to present time, with Union Bridge Co., Athens, Pa.

TONNELÉ, THEODORE, PH.B., ... 1880.
Care of Wm. Dewees Wood Co., McKeesport, Allegheny Co., Pa.
In charge of Refining and Steel Departments of the William Dewees Wood Company.

TOWER, FREDERIC WETHERWAX, E.M., . . . 1887.
Assistant Examiner, Room 223 Patent Office, Washington, D. C.

TOWNSEND, S. G. F., E.E., ... 1896.
Assistant in Electrical Engineering, Columbia University, and 131 Fifth Avenue, New York City.

TRAPHAGEN, FRANK WEISS, PH.B., PH.D., . . . 1882.
Chemist in charge of Chemical Laboratory, Montana College of Agriculture, Bozeman, Mont.
1883–84, Chemist for Williams, Clark & Co., Fertilizers. 1884–87, Instructor in Chemistry and Physics, Staunton Military Academy, Staunton. Va. 1887, Professor of General, Analytical and Applied Chemistry and Assaying in the College of Montana and Montana School of Mines. 1884–87, Analytical and Consulting Chemist, Staunton, Va. 1887, Principal work, fertilizer, iron and steel, clays, etc. Analytical and Consulting Chemist and Assayer, Deer Lodge, Mont. Assaying, miscellaneous analysis and legal work. 1890, Assayer for the Cham-

pion Consolidated Mining Company, Deer Lodge, Mont. 1892-93, in charge Montana Mining Exhibit at Columbian Exhibition. 1893, Professor Chemistry, Montana College of Agriculture and Mechanical Arts. 1895, Chemist Montana Agricultural Experiment Station.

TRASK, GEORGE FRANCIS DONNELL, E.M., . . 1887.

Contracting Engineer, 99 Cedar Street, New York City, and 12 Tompkins Avenue, New Brighton, S. I., N. Y.

1888-90, Apprentice and Machinist, L. & N. Railroad. 1890-91, Draughtsman, L. & N. Railroad, Louisville. In 1895-96, doing business as George F. D. Trask, Electric Railway Contractor ; in 1896, as member of Trask, Burns & Co., Electric Railway Contractors. 1898, Secretary and Treasurer, The Central Contracting Co.

TUSKA, GUSTAVE ROBITSCHER, B.S., M.S., C.E., . 1891.

29 Broadway, and 103 W. Fifty-eighth Street, New York City.

1891-92, Civil and Mechanical Engineer Link-Belt Engineering Co., Philadelphia. 1892-93, Bridge Engineer, Long Island Railroad. Assistant Engineer C. N. Y. and W. R. R., in charge of Stony Brook viaduct, 1893. Consulting Engineer Port-au-Prince Ry., Cuba, 1893 to date. Resident Engineer, Knoxville, Cumberland Gap and Louisville R. R. Co., in charge of Construction of Louisville Viaduct, 1893. Assistant to Professor of Civil Engineering, Columbia College, 1893. Tutor in Civil Engineering, School of Mines, 1894-95. 1896 to date, Chief Engineer Panama Railroad Co., and in general practice as Consulting Engineer.

TUTTLE, EDGAR GRANGER, E.M., ... 1881.

227 Pearl Street, New York City.

1881, Assistant Engineer Tilly Foster Iron Mine, Brewster, N. Y. 1881-82, Division Engineer, Wheeling and Lake Erie R. R., Toledo, O. 1882-83, Assayer and Mining Engineer, Silver City, New Mexico. 1883-85, Division and Office Engineer, Arizona and New Mexico Railroad, Lordsburg, Arizona. 1885, Constructing Engineer at Mines, Arizona Copper Co., Clifton, Arizona. 1885-89, Mining Engineer, Cambria Iron Co., Johnstown, Pa. 1889-94, Superintendent Alamo Coal Co., and Coahuila Coal Co., San Felipe, Coahuila, Mexico. Box 109, Eagle Pass, Texas. 1894, Examinations in Deep River Coal Field for Egypt Coal Co., North Carolina. 1894, Examination in Pocahontas Field, West Virginia. 1895, Writing "Surface Arrangements of Bituminous Mines," for Correspondence School of Mines, Scranton, Penna. 1895, Expert Examinations of Property and Operations of Columbus and Hocking Coal and Iron Co., Columbus, Ohio, for Bondholders' Committee.

TYLER, WALTER LINCOLN, C.E., ... 1887.

116-120 Front Street, and 1314 Pacific Street, Brooklyn, N. Y.

1887, Levelman and Transitman on the Roanoke and Southern Railroad, Va. 1888, with J. A. Latham, C.E., Providence, R. I. 1888-89, with F. N. Owen, E.M., Sanitary Engineer, New York City. 1889 to the present time, with the A. B. See Manufacturing Co., 116-120 Front Street, Brooklyn.

V.

VAIL, LEWIS H., E.E., ... 1894.

Locust Valley, Long Island, N. Y.

VANDERBILT, WILLIAM D., C.E., ... 1894.
39 Monroe Place, Brooklyn, N. Y.

VANDERPOEL, FRANKLIN, E.M., PH.D., . . . 1875.
Chemist, The Celluloid Co., 295 Ferry Street, Newark, N. J., and 153 Center Street, Orange, N. J.
1875–78, Salesman, with E. B. Benjamin. 1878 to date, as above.

VAN ARSDALE, WILLIAM HENRY, A.B., A.M., E.M., . 1868.
184 La Salle Street, Chicago, and Aurora, Ills.

VAN CORTLANDT, EDWARD NEWENHAM, E.M., . . 1885.
Gorontalo, Island Celebes, Care of Netherland Trading Society, Dutch East Indies.

VAN DEVENTER, CHRISTOPHER, E.E., . . . 1897.
300 Temple Avenue, Knoxville, Tenn.

VAN GELDER, ARTHUR P., PH.B., ... 1896.
Rapanno Chemical Co., Chester, Pa.
1896–97, Assistant Chemist of the Hygeia Sparkling Distilled Water Co., of New York. 1896–97, Assistant in Chemistry in the College of Physicians and Surgeons. 1897–98, Tutor in General Chemistry, Columbia University.

VAN DYCK, WM. VAN B., B.S., E.E., . . . 1897.
American Luxfor Prism Co., 160 Fifth Avenue, New York City, and 84 College Avenue, New Brunswick, N. J.

VAN SINDEREN, HOWARD, PH.B., ... 1881.
Attorney and Counselor-at Law, 35 Wall Street, and 14 West Sixteenth Street, New York City.

VAN VOLKENBURGH, EDWARD, JR., C.E., . . . 1888.
Morgan & Bartlet, 41 Wall Street, New York City.

VONDY, RUDOLPH HARRISON, E.M., ... 1882.
44 Kensington Avenue, Jersey City, N. J.
1882–83, Assistant Engineer, Tilly Iron Foster Mine. 1885–92, Chemist Phœnix Iron Works, Phœnixville, Pa. 1892, Superintendent Plenty Hort'l and Skylight Works.

VON NARDROFF, ERNEST ROBERT, E.M., . . . 1886.
Instructor, Erasmus Hall High School, Flatbush, and 360 Tompkins Avenue, Brooklyn, N. Y.

VREDENBURGH, WATSON, JR., C.E., ... 1898.
R. W. Hildreth & Co., 32 Broadway, and 225 W. 139th Street, New York City.
Previous to entering college served 4 years in office of R. W. Hildreth & Co. Summers during college course as Inspector for R. W. Hildreth & Co. Since graduation, Bridge Inspector, representing R. W. Hildreth & Co., New York City, and The Osborne Co., Civil Engineers, Cleveland, Ohio.

VULTÉ, HERMAN T., PH.B., PH.D., ... 1881.

Instructor in Chemistry, College of Physicians and Surgeons, 437 W. Fifty-ninth Street, New York City, and 33 Park Avenue, New Rochella, N. Y.

1881–82, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1883–92, Assistant Instructor in Analytical Chemistry, School of Mines. Tutor in Chemistry, 1892–1897, Instructor in Chemistry. Professor of Chemistry, Barnard College, 1892 to date. Engaged in investigating new Analytical Methods. Speciality, Commercial Organic Analysis Expert in Oils, Fats, Soap, etc.

W.

WAINWRIGHT, JOHN HOWARD, PH.B., . . . 1882.

Member of firm Simonds & Wainwright, 159 Front Street, and 22 W. Forty-sixth Street, New York City, N. Y.

1882, Chemist, Sanderson Bros. Steel Co., Syracuse, N. Y. 1883–1898, Chemist U. S. Gov't Laboratory, Appraiser's Office, N. Y. Resigned government office April, 1898, and now associated in partnership with F. M. Simonds, class 1887, forming firm of Simonds & Wainwright, Chemical and Mining Engineers and Analysts.

WALKER, ARTHUR LUCIEN, E.M., ... 1883.

General Manager Baltimore Electric Refining Company, Keyser Building, Baltimore, Md.

1893–84, Chemist and Assayer, Old Dominion Copper Co., Globe, Arizona. 1885, Assistant Superintendent in same company. 1886, engaged in connection with Iron Metallurgy in New York City. 1887, Mechanical Engineer for Silver King Mining Co., Silver King, Arizona. 1888–93, Superintendent, Old Dominion Copper Co., Globe, Arizona. Also report on all classes of Mining and Metallurgical Property in Arizona. 1893–95 Consulting Engineer Old Dominion Copper Co. 1893 to 1897, Manager Baltimore Electrolytic Refining Co., Baltimore, Md. 1898, Manager Baltimore Copper & Rolling Co.

WALKER, H. V., PH.B., ... 1894.

38–40 Clinton Street, Brooklyn, N. Y.

WALLER, ELWYN, A.B., A.M., E.M., PH.D., . . 1870.

7 Franklin Place, Morristown, N. J.

1871, Assistant Analytical Chemistry, School of Mines. 1877, Instructor Analyt, ical Chemistry, School of Mines. 1885–93, Professor of Analytical Chemistry-School of Mines. 1872–85, Inspector and Chemist, N. Y. Health Department.

WAMPOLD, LEO, PH.B., ... 1888.

204 Monroe Street, Chicago, Ill.

WARD, DELANCY WALTON, PH.B., ... 1888.

Whitestone, N. Y.

WARNER, JOSEPH LOWERY, E.M., ... 1887.

P. O. Box 621, Spokane, Wash.

August, 1887, to August, 1888, Omaha and Great Smelter, Denver, Assistant

Assayer. August, 1888, to July, 1889, Examination of and Reports on Mines in Cœur d'Alene, Idaho, and in O'Kanagrn Mining District, Washington. Manager La Bellevue Mine, same district. July, 1889, to January, 1890, Assistant Superintendent and Amalgamator, Golden Monarch Mine, Oregon. January, 1890–92, Examination and Reports on Mines in Western Washington. Manager, Culver Mining Co. and V. P. Vermilion Iron Co. 1892, Examinations in Cascade Range. 1893, Examinations of Iron Deposits, Island of Texado, British Columbia.

WATSON, FREDERICK MORGAN, E.M., . . . 1885.

Care of Simmer & Jack, box 67, Johannesburg, South Africa, via London, and 403 Sibley Street, Cleveland, O.

1885, Assayer and Surveyor, La Maria Mining Co., Mexico. 1888–89, Engineer, Mill Superintendent, Sembrerete Mining Co., Mexico. Concentration and Lixiviation. 1890, Engineer for Peruvian Exploration Syndicate, Ltd., Peru. 1891 to date, Examining Engineer, for Frecheville Bros. Special Experience in Roasting Rebellious Ores. Lixiviation by Russell Process and Superintendent as above. Superintendent "Compania Andes" till 1896. 1896, Engineer Consolidated Gold Fields of South Africa. 1896 to date, Superintendent, Simmer & Jack Gold Mining Co., Germiston, Johannesburg, S. A.

WATSON, ROLLA BARNUM, E.M., ... 1891.

Care Mexican Copper Co., Ramos, San Luis, Potosi, Mexico.

Assayer, Candemena, Mexico, 1891. 1892, Erecting Power Plant for Electric Street R. R., Atlanta, Ga. September, 1893, with Dewey-Walter Refining Co., Park City, Utah. December, 1893 to date, Superintendent Dewey-Walter Refining Co. May, 1895, Foreman Marsac Leacher. 1896 to date, Asst. Mgr. Russell Process Co. May, 1898, Supt. Marsac Mill for Ontario Silver Mining Co.

WEED, WALTER HARVEY, E.M., ... 1883.

U. S. Geological Survey, Washington, D. C., and care S. R. Weed, South Norwalk, Conn.

1883 to date, Geologists on the United States Geological Survey.

WEEKS, WILLIAM HOLDEN, PH.B., ... 1889.

789 Madison Avenue, New York City.

1889–90, Assistant Chemist, New York Chemical Manufacturing Company. April, 1890, to date, Assistant Chemist Health Department, New York City.

WELCH, ALEXANDER MCMILLAN, PH.B., (Arch.), . 1890.

503 Fifth Avenue and 15 E. Seventy-first Street, New York City.

1890–91, in architect's office. 1891–93, McKim Fellow, travelling in Europe. 1893 to date, as above.

WELLS, JAMES SIMPSON CHESTER, PH.B., PH.D., . 1875.

Columbia University, New York City, and 221 Union Street, Hackensack, N. J.

1875–79, Assistant in Quantitative Analysis, School of Mines. Vacation of 1877, spent as Night Superintendent Pennsylvania Lead works. 1879–93, Instructor in Qualitative Analytical Chemistry, School of Mines.

WESTERVELT, WILLIAM Y., E.M., ... 1894.

Member of Firm, Case & Westervelt, 100 William Street, New York City.

1894–95, Chemist and Surveyor, Ducktown Sulphur. Copper and Iron Co., Ltd. 1895–96, Engineer and Chemist, same company. 1896, Acting Mining Superintendent, same company. 1897, Superintendent of Mines, same company.

WHEELER, HERBERT ALLEN, E.M., ... 1880.
1416 Chemical Building and 3124 Locust Street, St. Louis, Mo.

During 1880, Assistant Geologist in Utah, on U. S. Geological Survey. During 1881, Assistant Engineer Denver and Rio Grand Western Railroad, in Utah and Colorado, on location and construction. During 1882, Superintendent Vermont Copper Company, Ely, Vermont. From 1883 to 1884, at Washington University. St. Louis; Adjunct Professor of Mining; also Consulting Mining Engineer, Since 1891, Assistant Missouri Geological Survey. 1894, Consulting Mining Engineer. 1896, Secretary and Treasurer, Standard Tile Co.

WHITE, ROBERT DAVIS, C.E., ... 1892.
Chief Draughtsman, C. W. Hurst Co., Staten Island and *for Mail*
39 F. Seventy-fourth Street, New York City.

WHITE, THEODORE GREELEY, PH.B., M.A., . . 1894.
Department of Physics, 210 Fayerweather Hall, Columbia University, and 39 West Twenty-sixth Street, New York City.

Summer of 1893, working on the Geology of the Lake Champlain region. Summer of 1894, traveling and examining mining regions surrounding the Great Lakes in Canada and United States, also researches on the Geology of Mt. Desert Island, Maine. 1894 and 1895, Post-graduate student in Geology. Researches on the Trenton formation of the Lake Champlain Valley. 1895–96, Lecturer, N. Y. Board of Education. Summer 1897, N. Y. State Museum. Summer 1898, Researches on the Geology of the Boston Basin. 1896 to date, Assistant in Physics, Columbia University.

WHITE, WM. S., E.M., ... 1882.
Department of Docks, Pier A., North River, New York City, and Hillside Avenue, Englewood, N. J.

At present Assistant Engineer in charge of construction on the North River Water Front of New York City.

WHITING, LOWE, E.M., ... 1895.
926 E. Nineteenth Street, Minneapolis, Minn.

WHITLOCK, HERBERT PERCY, C.E., ... 1889.
Assistant in Mineralogy, Columbia University School of Mines, and 449 Park Avenue, New York City.

WIECHMANN, FERDINAND G., PH.B., PH.D., . . . 1881.
771 West End Avenue, New York City.

Consulting Chemist American Sugar Refining Co., Brooklyn, N. Y.

WIENER, WILLIAM, A.M., PH.B., ... 1891.
Newark High School, and 62½ Nelson Place, Newark, N. J.

1891-92, Chemist to the Hanson, Van Winkle Co., Newark, N. J. 1892–93, Chemicals for Electro-plating. 17 and 19 Mechanic Street, Newark, N. J. 1893 to date, Instructor in Newark High School and general chemical practice.

WILLIAMS, JOHN TOWNSEND, E.M., PH.B., . . 1873.

Architect and Builder, Lord's Court Building, 27 William Street, Room 1204, New York City, and Stamford, Conn.

WILLIAMS, WILLIAM FISH, C.E., E.M., . . . 1881.

City Engineer and 2 Court Street, New Bedford, Mass.

Chief Engineer, later also Assistant Manager to Cumberland Lands, Ltd., of Stewart County, Tenn. 1890–93, City Engineer, New Bedford, Mass. 1893 to present time, also Chief Engineer at present on the construction of the New Bedford and Fairhaven Bridge.

WILLIS, BAILEY, E.M., C.E., ... 1878.

United States Geological Survey and 2117 Bancroft Place, Washington, D. C.

June, 1879, to July, 1881, Special Agent Tenth Census; sample of iron ores and student of iron deposits in States east of the Mississippi river. August, 1881, to June, 1884, Geologist in charge of Pacific division of Northern Transcontinental Survey, chiefly engaged in coal explorations in Washington, Oregon and Montana. July, 1884, to February, 1889, Assistant Geologist, U. S. Geological Survey, working in Tennessee and North Carolina. March, 1889, to June, 1893, Geologist in charge of Appalachian division, U. S. Geological Survey, directing work and studying geologic problems of the Palæozoic rocks south of Pennsylvania. 1891–93, Editor of Geologic Maps for Folios of the Geologic Atlas of the United States. In 1895-96, Geologist in charge of operations in the Cascade Range and Puget Sound Basin, Washington.

WILSON, HERBERT M., C.E., ... 1881.

U. S. Geological Survey, Washington, D. C.

1881–82, Leveller and Transitman, afterwards Chief of Preliminary party, S. & D. R. R., Mexico. 1882–88, Topographer U. S. Geological Survey. 1889-90, Division Engineer, U. S. Irrigation Surveys. 1891, Geographer, U. S. Geological Survey. 1894, Chief Geographer. 1897, Geographer in charge of Atlantic Section.

WILSON, WILLIAM ALEXANDER, E.M., . . . 1882.

Chamber of Commerce, Salt Lake City, Utah.

Assayer for two and a-half years. Superintendent of Sampling Mill for two years. Superintendent of 30-Stamp Mill (dry crushing, chloridizing, amalgamating and lixiviating capacity sixty tons per day) for five years. Specialty, treatment of silver and gold ores and examining and reporting on mining properties. Superintending of Mining or Milling operations. U. S. Deputy Mineral Surveyor.

WILTSEE, ERNEST ABRAM, E.M., ... 1885.

Crocker Building, San Francisco, Cal.

1885–86, Assistant Chemist Edgar Thompson Steel Works, Braddock, Pa. 1886 to May, 1887, Chemist Colorado Coal and Iron Company, Pueblo, Col. May, 1887, to August, 1888, Chemist for the Globe Smelting and Refining Company, Denver, Col. August, 1888, to April, 1890, Assistant Superintendent North Star Mining Company, Grass Valley, Cal. April, 1890–91, Superintendent Menlo Mines, Grass Valley, Cal. January, 1892, Expert work, Nevada County, Cal.

January to August, 1892, with California State Mining Bureau. August, 1892, to January, 1893, Expert work through California. April, 1893, Manager Gold Mines for Barnato Bros., Johannesburg, South Africa. July 1, 1894, Eldenhuis Est and Gold Mining Co., Johannesburg, South Africa Republic.

WITTMACK, CHARLES AUGUSTUS, M.S., PH.B., PH.D., . 1882.
1 West 102nd Street, New York City.

WOOLSON, IRA HARVEY, E.M., ... 1885.
Columbia University, New York City.

1885–86, Assistant Geological Survey of New Jersey. 1886–87, Assistant Assay Department, School of Mines. 1887–89, Assistant, Drawing Department School of Mines. 1891 to date, Instructor Mechanical Engineering and Drawing, Columbia University.

Y.

YRIZAR, ROBERTO, E.M., ... 1895.
A. P. 27 Zacatecas, Mexico, also care C. Viaders, 14–16 South William Street, New York City.

YOUNG, EDWARD LEAVITT, E.M., ... 1882.
American Buyer Takata & Co., of Tokio, Japan, 10 Wall Street, and 317 W. Eighty-ninth Street, New York City.

HONORARY MEMBERS.

BURR, WM. H.
Professor Civil Engineering, Columbia University. Address, 161 W. Seventy-fourth Street, New York City.

CHANDLER, CHARLES F., PH.D., M.D., LL.D.
Professor of Chemistry, Columbia University. Address, 51 E. Fifty-fourth Street, New York City.

EGLESTON, THOMAS, E.M., PH.D., LL.D.
35 W. Washington Square, New York City.

HOWE, HENRY M.
Professor of Metallurgy, Columbia University. Address, 27 W. Seventy-first, New York City.

MILLER, GEORGE M., A.M., LL.B.
West Nyack, New York.

ROOD, O. N., A.M.
Professor of Physics, Columbia University. Address, Columbia University, New York City.

VAN AMRINGE, J. H.., PH.D., L.H.D., LL.D.
Professor of Mathematics, Columbia University. Address, 66 W. Forty-seventh Street, New York City.

WARE, WILLIAM R., LL.D.
Professor of Architecture, School of Mines, Columbia University. Address, 126 E. Twenty-eighth Street, New York City.

HONORARY MEMBERS DECEASED.

AGNEW, C. R.,	1888.
BARNARD, F. A. P.,	1889.
NEWBERRY, J. S.,	1892.
PECK, W. G.,	1892.
RUTHERFURD, LEWIS M.,	1892.
TROWBRIDGE, W. P.,	1892.
FISH, HAMILTON,	1893.

LIST No. 3.

Contains the names of Graduates of the School of Mines, not members of the Alumni Association, nor participating in the benefits of such membership. For this reason great uncertainty prevails as to many of the addresses given, which are the best at hand, and should any corrections be noted the Secretary will be glad to be advised of them.

It is very desirable that this list should be shortened as far as practicable by the transfer of names from it to the preceding List, No. 2, under the Rules.

(Revised to January, 1899.)

Achen, J. B., Ph.B., ... 1894.
Hawarth, N. J.

Adams, W. J., A.M., E.M., ... 1878.
Room 15, No. 132 Market St., San Francisco, Cal.

Adams, W. C., C.E., ... 1884.
47 West 28th St., New York City.

Agramonté, José Cesar, C.E., ... 1886.
Address unknown.

Agromonté, E., C.E., ... 1886.
110 Lexington Avenue, New York City.

Agramonté, I. E., C.E., ... 1883.
Zulieta No. 3, Havana, Cuba.

Alden, Herbert C., E.M., ... 1884.
Address unknown.

Aldrich, C. H., Ph.B., ... 1893.
8 Cushing St., Providence, R. I.

Allen, C. S., Ph.B., M.D., ... 1874.
Address unknown.

Anderson, George Mendenhall, Ph.B., ... 1891.
East Walnut Hills, Cincinnati, Ohio.

Andresen, Charles Alfred, E.M., ... 1881.
Pickard & Andresen, 89 Gold Street, New York City.

Anthon, C. L., E.E., ... 1898.
220 East 123d Street, New Yor City.

Appleby, John Storm, Ph.B., A.M., ... 1888.
Architect, 216 West Fifty-ninth Street, New York City.

Arendt, M., E.E., ... 1898.
42 West 126th Street, New York City.

Arden, John L., Ph.B., E.E., ... 1896.
Garrison, N. Y.

Aschman, Fred. Theo., Ph.B., ... 1881.
Chemist and Professor of Chemistry, College of Pharmacy.

Auryansen, Fredh., C.E., ... 1896.
Piermont, N. Y.,
and 86 Water Street, Pittsburg, Pa.

Ayestas, Alberto, Ph.B., ... 1883.
Tegucicalpa, Honduras, C. A.

Ayres, W. C., Ph.B., ... 1893.
Address unknown.

Baker, George L., Ph.B., ... 1888.
Address unknown.

Bardwell, A. F., E.M., ... 1886.
Box 773 Aspen, Colo.

Barnard, Aug. Porter, E.M., ... 1868.
125 East Twenty-sixth Street, New York City.

Barnes, W. C., E.E., ... 1897.
505 Broadway, Paterson, N. J.

Barros, Louis de Souza, E.M., C.E., ... 1877.
Address unknown.

Bartlett, F. R., C.E., ... 1880.
344 Madison Street, Brooklyn, N. Y.

Baxter, D. E., C.E., ... 1897.
32 West Sixtieth Street, New York City.
Baxter, George S., A.B., E.M., ... 1868.
77 Broad Street, New York City.
Beadel, H. L., B.S., ... 1898.
120 Front Street, New York City.
Beckstein, Charles Alfred, Ph.B., ... 1888.
336 West Forty-sixth Street, New York City.
Beckwith, Charles Ellsworth, Met. Eng. . . . . 1888.
Address unknown.
Beckwith, George Alexander, C.E., ... 1890.
Paterson, N. J.
Behlem, Herman, Ph.B., ... 1890.
125 East One Hundred and Fifteenth Street, New York City.
Behr, Edward, C.E., ... 1877.
426 Henry Street, Brooklyn, N. Y.
Bell, Henderson M., Jr., E.M., ... 1886.
Brambell, Mercer Co., W. Va.
Bellman, J. J., E.E., ... 1897.
90 King Street, New York City.
Bemis, F. P., ... 1885.
Whitaker Block, Davenport, Iowa.
Bennett, G. L., M.E., ... 1898.
208 Putnam Avenue, Brooklyn, N. Y.
Bentley, W. A., M.E., ... 1898.
161 West 108th Street, New York City.
Bergen, Chas. Hill, C.E., ... 1692.
Red Bank, N. J.
Berry, Gerald, C.E., ... 1889.
78 Morton Street, Brooklyn, N. Y.
Black, Alex. L., E.M., ... 1890.
56 Carondelet Street, New Orleans, La.
Bliss, Collins Pechin, Ph.B., ... 1891.
60 Cedar Street, Room 9, New York City.
Blydenburgh, Chas. E., A.B., A.M., E.M., ... 1878.
Box 180 Rawlings, Wyoming.
Boehm, Geo. A., Ph.B., ... 1897.
33 West 89th Street, New York City.
Bolles, Randolph, Ph.B., ... 1892.
Englewood, N. J.
Bolton, Robert, Ph.B., M.D., ... 1879.
Assistant Physician, Essex County Insane Asylum, So. Orange Av.,
Newark, N. J.
Bossange, E. R., Ph.B., ... 1893.
75 West Forty-fifth Street, New York City.
Bostwich, W. A., M.E., ... 1898.
324, West Forty-sixth Street, New York City.
Brennan, Andrew Joseph, C.E., ... 1885.
Address unknown.
Bridgham, Samuel Willard, E.M., ... 1867.
49 West Twenty-third Street, New York City.

Brinckerhoff, George Charles, E.M., ... 1878.
Apartado 183, Matanzas, Cuba.

Bronson, Edward Stelle, A.B., A.M., E.M., ... 1867.
49 Garden Place, Brooklyn, N. Y.

Brooks, W. F., Ph.B., ... 1893.
335 West Fifty-fifth Street, New York City.

Brosnan, F. X., C.E., ... 1891.
146 West Seventy-fourth Street, New York City.

Brown, Alex. M., E.M., ... 1897.
245 West Fifty-fourth Street, New York City.

Brown, F. G., E.M., ... 1867.
15 Whitehall Street, New York City.

Brown, H. D., C.E., ... 1898.
9 West 129th Street, New York City.

Browning, J. H. B., M.D., ... 1880.
Smithtown, L. I., N. Y.

Bruckman, Frederick, E.M., ... 1867.
U. S. Mint and 120 West Third Avenue, Denver, Colo.

Brugman, Wm. F., Ph.B., ... 1880.
Los Angeles, California.

Bryce, Wm. Jr., Ph.B., ... 1884.
40 West Fifty-fourth Street, New York City.

Buckingham, Frederick Endicott, E.M., ... 1884.
Department Public Works, Brooklyn, N. Y.

Buckland, Will. A., Ph.B., ... 1890.
36 East Twenty-second Street, New York City.

Bullman, Chas., Ph.B., ... 1883.
808 3d Place, Plainfield, N. J.

Burnside, C. H., B.S., ... 1898.
372 W. 120th Street, N. Y. City.

Burritt, W. W., ... 1884.
Englewood, N. J.

Burrill, Percy M., E.M., ... 1896.
Bartow-on-Sound, N. Y., and 56 East 49th Street, New York City.

Burroughs, H. S., E.E., ... 1897.
1416 Pacific Street, Brooklyn, N. Y.

Bush, E. R., E.M., ... 1881.
104 John Street, New York City.

Bush, William Falkner, E.M., ... 1885.
Address unknown.

Butler, Wm. C., Met. E., ... 1887.
Everett, Wash.

Cady, Linus B., E.M., C.E., ... 1877.
Address unknown.

Campbell, Alonzo Clarence, E.M., ... 1869.
Mining Engineer, 306 Russell Street, Nashville, Tenn. Specialty, Milling and Concentration.

Campbell, A. J., E.M., ... 1898.
120 West 81st Street, New York City.

Canfield, A. E., E.M., ... 1877.
Address unknown.

Canfield, M. C., E.E., ... 1893.
18 Clinton Street, Cleveland, Ohio.

Carney, Edward J., C.E., ... 1896.
67 West 68th Street, New York City.

Carrère, Joseph Maxwell, C.E., ... 1883.
36 Park Place, New York City, and New Brighton, N. Y.

Carson, Joseph, C.E., ... 1890.
31 West Fifty-fifth Street, New York City.

Cary, Geo. B., Ph.B., ... 1895.
184 Delaware Avenue, Buffalo, N. Y.

Chapman, A. W., E.E., A.B., ... 1894.
160 Hicks Street, Brooklyn, N. Y.

Chatain, H. G. F. J., E.E., ... 1897.
42 West Ninetieth Street, New York.

Chazel, P. E., ... 1881.
56–58 Broad Street, Charleston, S. C.

Clark, F. S., E.M., Ph.D., ... 1885.
527 Madison Avenue, New York City.

Clark, J. H., E.M., ... 1897.
Paterson, N. J.

Clark, Leroy, Jr., E.E., ... 1894.
359 West Fiftieth Street, New York City.

Clayton, William Robert, Ph.B., ... 1890.
Architect, 31 and 32 Rialto Building, Chicago, Ill.

Collins, C. L., 2d, E.E., ... 1897.
323 Palisade Avenue, Yonkers, N. Y.

Cloud, Leo George, A.B., E.M., ... 1879.
216 Mammouth Street, Newport, Ky.

Colton, Frederick Gray, Ph.,B., ... 1890.
136 Montague Street, Brooklyn, N. Y.

Colt, S. B., Ph.B., ... 1888.
1197 Broad Street, Newark, N. J.

Comstock, Claude Nichols, C.E., ... 1888.
Address unknown.

Congdon, H. W., Ph.B., ... 1897.
194 Clinton Street, Brooklyn, N. Y.

Constant, Charles Louis, E.M., C.E., ... 1877.
32 Park Street, Jersey City, N. J.

Corcoran, J. T., E.M., ... 1884.
131 Smith Street, Brooklyn, N. Y.

Cornell, George B., E.M., C.E., ... 1877.
29 Broadway and 46 West 48th Street, New York City.

Cornwall, George Rockwell, E.M., C.E., ... 1876.
189 Lefferts Place, Brooklyn, N. Y.

Cornwall, H. C., E.M., ... 1879.
Commonwealth Ins. Co., Nassau Street, New York City.

Coursen, George Hampton, E.M, C.E., ... 1868.
Address unknown.

Covell, E. C., A.B., ... 1892.
Address unknown.

Covell, W. S., Ph.B. . . . . 1893.
42 W. Sixty-sixth Street, New York City.
Coykendall, Thomas Cornell, C.E., ... 1890.
Rondout, N. Y.
Cozzens, Harmon, E.M. . . . . 1885.
Address unknown.
Crampton, S. H., E.E., ... 1897.
95 Gates Avenue, Brooklyn, N. Y.
Cristy, Edward Buxton, Ph.B., ... 1891.
Albuquerque, New Mexico.
Cromwell, James William, Jr., Ph.B., ... 1889.
Architect, 29 Brevoort Place, Brooklyn, N. Y.
Crowell, Charlez B., Ph.B., ... 1885.
Minneapolis, Minn.
Curtis, Charles Gordon, C.E., ... 1881.
President Curtis Electrical Mfg. Co., Whiton St., Jersey City, N. J.
Curtiss, C. C., A.B., A.M., ... 1892.
Address unknown.
Darrach, J. M. A., Ph.B., ... 1896.
Morristown, N. J.
Davis, William Monroe, E.M., ... 1890.
Syracuse, N. Y.
Del Calvo, Francis, C.E., ... 1884.
Address unknown.
Dodsworth, W. A., Ph.B., ... 1888.
19 Beaver Street, New York City.
Donnell, H. E., Ph.B. . . . . 1887.
Address unknown.
Doolittle, Charles Horace, E.M., ... 1885.
Address unknown.
Dowie, Horace, A. B., E.E., ... 1896.
363 Jefferson Avenue, Brooklyn, N. Y.
Downing, Orrien Pinkerton, Ph.B., ... 1878.
116 Battery Street, San Francisco, Cal.
Dunn, A. D., E.E., ... 1898.
164 W. 111th Street, New York City.
Dunn, Gano Sillick, B. S., E.E., ... 1891.
Elect. Engineer, Crocker-Wheeler Electric Co., Ampere, East Orange, N. J.
Durham, Edward B., E.M., ... 1892.
Mt. Kisko, N. Y.
Dutcher, B. H., Ph.B., ... 1892.
Asst. Surgeon, U. S. A., Ft. Leavenworth, Kansas.
Eastwick, Edward P., Jr., Ph.B., C.E., ... 1896.
Am. Sugar Ref. Co., New Orleans, La.
Eddie, E. C., E.M., ... 1885.
Address unknown.
Eliot, Walter Greame, E. M., C.E., Ph.B., Ph.D., ... 1878.
"University Magazine," 70 South St., and University Club, New York City.
Ellis, A. Van Horn, C.E., ... 1889.
Bartow-on-Sound, N. Y.

Emanuel, L. V., C.E., ... 1896.
925 Park Avenue, New York City.

Emery, H. G., Ph.B., ... 1894.
Nyack, N. J.

Escobar, Francisco, E.M., ... 1889.
842 Wilson Avenue, Cleveland, Ohio.

Fales, William, E. S., E.M., LL.B., ... 1871.
Amoy, China.

Falk, D. B., C.E., ... 1882.
Savannah, Ga.

Farmer, A. S., C.E., ... 1897.
147 South Fifth Street, Brooklyn, N. Y.

Fellows, William K., Ph.B., ... 1894.
7818 Eggleston Avenue, Chicago, Ill.

Fenner, Clarence Norman, E.M., ... 1892.
Paterson, N. J.

Ferguson, G., C.E., ... 1898.
Paterson, N. J.

Ferguson, George Albert, Ph.B., ... 1890.
138 Wilson Street, Brooklyn, N. Y.

Fisher, Lloyd Wiegand, Ph.B., ... 1890.
109 E. Twenty-eighth Street, New York City.

Fitch, Charles Lincoln, E.M., ... 1882.
Address unknown.

Fitch, Josiah Huntingdon, E.M., ... 1884.
Address unknown.

Fitzgerald, George, E.M., ... 1884.
El Paso, Texas.

Floyd, F. W., C.E., M.M., ... 1877.
529 W. Twentieth Street, New York City.

Force, D. N., Jr., E.E., ... 1897.
Montclair, N. J.

Fowler, A. C., C.E., ... 1889.
Cienfuegos, Cuba.

Francke, Robert Otto, C.E., ... 1880.
W. Passburg, Esq., Moscow, Russia.

Frankfield, Emil, C.E, ... 1886.
328 W. Fifty-sixth Street, New York City.

Franklin, L. M., Jr., Ph.B., ... 1896.
Flushing, L. I., N. Y.

Frisbee, H. D., E.E., ... 1894.
Fulton Street, New York City.

Fuentes, Paul, E.M., ... 1894.
321 Hudson Street, Hoboken, N. J.

Fulton, C. H., E.M., ... 1897.
229 Fifth Avenue, Brooklyn, N. Y.

Gage, Samuel Edson, Ph.B., ... 1887.
Architect, 144 Fifth Avenue, New York City.

Gardner, Watts Denning, C.C., ... 1888.
Board of Health, New York City.

Garrison, Edmund Hoyt, E.M., C.E., ... 1876.
84 Highland Street, Yonkers, N. Y.
Geer, George Jarvis, Jr., E.M., ... 1868.
Merchant, 453 Broome Street, New York City.
Geppert, R. M., E.M., ... 1898.
20 Mercer Street, Newark, N. J.
Giddings, Edward Everett, E.M., ... 1867.
Merchant, 413 Royal Insurance Building, Chicago, Ill.
Gill, A. W., C.E., ... 1897.
Leonia, N. Y.
Goodman, M., C.E., ... 1898.
338 E. Fourth Street, New York City.
Goodridge, J. W., C.E., ... 1897.
Brooklyn, N. Y.
Goldsmith, Byron, Benjamin, Ph. B., ... 1887.
19 E. Seventy-fourth Street, New York City.
Goldsmith, Goldwin, Ph.B., ... 1896.
New Rochelle, N. Y.
Gould, Edward Ludlow, C.E., ... 1890.
59 Hawthorne Avenue, Yonkers, N. Y.
Gotthelf, A. H., Ph.B., ... 1897.
Hastings, N. Y.
Gottschall, L., B.S., ... 1898.
207 East 53rd Street, New York City.
Greene, Wilkins Updike, Ph.B., ... 1880.
104 Columbia Heights, Brooklyn, N. Y.
Gregory, L. E., C.E., ... 1893.
406 Passaic Avenue, Kearney, N. J.
Griffin, S. P., Jr., ... 1884.
449 Park Avenue, New York City.
Griffiths, Vincent Colyer, Ph.B., ... 1889.
160 Herkimer Street, Brooklyn. N. Y.
Griggs, Wilfred Elizur, Ph.B., ... 1889.
Architect, Waterbury, Conn.
Griswold, Wm. T., C.E., ... 1881.
U. S. Geol. Survey, Washington, D. C.
Haas, Harry Leopold, Ph.B . . . . . 1878.
Carrére and Haas, 36 Park Place, New York City.
Haldy, Geo. F., E.E. . . . . 1897.
Cleveland, Ohio.
Hamilton, Schuyler, Jr., A.B., A.M., E.M., ... 1876.
Croton-on-Hudson, Westchester Co., N. Y., Architect and Brick M'f'r.
Hanson, R. C., C.C., ... 1894.
79 Manhattan Avenue, New York City.
Harker, Charles Sumner, E.M., ... 1879.
26 Montgomery Street, San Francisco, Cal.
Harmer, Thomas Hays, A.B., A.M., E.M., ... 1867.
113 East Twenty-seventh Street, New York City.
Harrison, Newton, E.E., ... 1892.
Electrical Engineer, 136 Liberty Street, New York City.

Hart, Burnham, C.E., ... 1885.
Ramsay, N. J.

Hart, Charles Henry, C.E., ... 1890.
199 Lennox Avenue, New York City.

Hasegawa, Yothinosuke, E.M., Ph.D., ... 1878.
Mitsu Bishi Sha, No. 11, Awajicho, Nichome Konda, Tokio, Japan.

Hawkes, Emil McDougal, A.B., E.M., ... 1885.
267 Fifth Avenue, New York City.

Hawks, H.D., E.E., ... 1896.
40, West Fifty-fifth Street, New York City.

Hay, Arthur, E.M., ... 1882.
821, South Second Street, Springfield, Ill.

Herckenrath, W. A., A.M., C. E., ... 1892.
Address unknown.

Heinze, Frederick Augustus, E.M., ... 1889.
General Manager, Montana Ore Purchasing Co., Butte, Montana.

Hesselbach, Chas, V., C.E., ... 1896.
93 Lexington Avenue, New York City.

Hemmer, Frederick Adolph, Ph.B., ... 1881.
Box 6, Edgewater, N. J.

Herz, Henry, Ph.B , ... 1897.
176 Newark Avenue, Jersey City, N. J.

Heye, Geo. G., E.E., ... 1896.
11 East 48th Street, New York City.

Hill, R. F., Jr., E.M., ... 1898.
31 East 75th Street, New York City.

Hodgson, E.H., B.S., ... 1898.
417 West 117 Street, New York City.

Hooker, Wm. H., A.B., A.M., E.M., ... 1869.
145 Broadway, New York City.

Hooper, Louis Mosher, C.E., ... 1880.
Rutherford, N. J.

Holbrook, F. M., E.E., ... 1897.
Columbia University, New York.

Holter, Norman Bernard, E.M., ... 1891.
A. M. Holter Hardware, Co., Helena, Mont.

Horn, James Thurston, A.B., C.E., ... 1884.
Naval Architect, and 13 East Fifty-third Street, New York City.

Hornbostel, Henry Frederick, Ph.B., ... 1891.
39 Second Place, Brooklyn, N. Y.

Hoyt, John Sherman, C.E., ... 1890.
934 Fifth Avenue, New York City.

Hoyt, R., C.E., ... 1893.
Katonah, N. Y.

Hoyt, W. L., C.E., ... 1876.
Globe Smelting and Refining Co., Denver, Col.

Hudson, Edward Henry, C.E., ... 1889.
Address unknown.

Humbert, W. S., E.M., ... 1883.
Niagara Falls, N. Y.

Humphreys, J. B., E.E., ... 1897.
23 East 47th Street, New York City.

Huntington, F. W., E.M., ... 1885.
Address unknown.

Huntting, Henry Ogden, Ph.B., ... 1887.
Architect, 454 Ceasson Avenue, Brooklyn, N. Y.

Hurlbert, E. D. Jr., C.E., ... 1890.
106 Hicks Street, Brooklyn, N. Y.

Hutchins, G. L., E.M., ... 1898.
Address unknown.

Hyatt, Chas. Edw., E.E., ... 1896.
Newark, N. J.

Ihlseng, M. C., C.E., Ph.D., ... 1875.
State College, Pa.

Ives, Arthur Stanley, C. E., E.E., ... 1889.
33 Sydney Place, Brooklyn, N. Y.

Jackson, Charles Edward, C.E., ... 1875.
15 Cortlandt Street, New York City.

Jacobs, H. H., Ph.B., ... 1894.
107 East Seventy-eighth Street, New York City.

Jarman, L. H., C.E., ... 1895.
112 Lefferts Place, Brooklyn, N. Y.

Jarmulowsky, Meyer, Ph. B., ... 1890.
27 Jefferson Street, New York City.

Jenney, Walter Proctor, E. M., Ph.D., ... 1869.
Rapid City, South Dakota.

Jeup, B. J. F., C.E., ... 1887.
119 Walcott Street, Indianapolis, Ind.

Joffe, Meyer, C.E., ... 1894.
Verona, N. J.

Jones, Thomas Jefferson, Met. Eng., ... 1890.
Pulaski City, Va.

Jones, Wm. D., Ph.B., ... 1888.
206 Produce Exchange, New York City.

Jones, W. P., E.E., ... 1898.
312 West 28th Street, New York City.

Jordao, Jos. Nabor Pacheco, C. E., E.M., Ph.B., ... 1877.
Address unknown.

Judd, Charles Breck, E.M., ... 1881.
Westinghouse Building, Pittsburg, Pa.

Judson, Hanford Chase, E.E., ... 1898.
Dobbs Ferry, N. Y.

Karr, C. P., Ph.B., ... 1878.
1 Union Square, West, New York City.

Kaufmann, Edwin, Ph.B., ... 1897.
49 East 66th Street, New York City.

Keeler, Frederick Sterling, Ph.B., ... 1891.
530 Bouch Avenue, Buffalo, N. Y.

Kilian, Wm. G., Ph.B., ... 1897.
352 West 33rd Street, New York City.

King, Charles, Ph.B., ... 1876.
Railroad contractor, King & Dickinson, Tacoma, Wash.
Kissam, H. S., Ph.B., ... 1886.
35 Wall Street, New York City.
Kletchka, John Joseph, A.B., C.E., ... 1892.
247 Willis Avenue, New York City.
Knapp, John Augustus, A.B., A.M., E.M., ... 1870.
Chicago and Aurora Smelting Co., Chicago, Ill.
Knox, Charles E., E.E., ... 1892.
Jas. W. Queen & Co., Philadelphia, Pa.
Koch, Richard, E.E. . . . . 1897.
47 East 78th Street, New York City.
Kohn, Robert David, Ph.B., ... 1890.
4 Rue Honoré Chevalier, Paris, France.
Korn, Louis, Ph.B., ... 1890.
261 Broadway, New York City.
Kraemer, Henry, Ph.G., Ph.D., ... 1895.
Professor of Botany, Philadelphia College of Pharmacy, Philadelphia, Pa.
Krumb, H., ... 1898.
55 Ten Eyck Street, Brooklyn, New York.
Langmuir, A. C., ... 1893.
Waverly, N. J.
Leavens, H. W., E.M., ... 1875.
Broken Hill Refinery Co., Bort Pirie, Australia.
Ledoux, Augustus Damon, Ph.B., ... 1881.
P. O. Box 426, Richmond, Va.
Lee, Henry Charles, C.E., ... 1886.
127 East 21st Street, New York City.
Lewis, C. McK., ... 1898.
104 East 37th Street, New York City.
Lichtenstein, Edward Gervaise, Ph.B., ... 1890.
14 West 74th Street, New York City.
Lindsley, Stewart, E.M., ... 1870.
Orange, N. J.
Livingston, Goodhue, Ph.B., ... 1892,
George B. Post, Century Building, New York City.
Livingston, J., Jr., E.E., ... 1898.
56 East 49th Street, New York City.
Lobo, G., E.E., ... 1898.
219 West 44th Street, New York City.
Lord, Nathaniel Wright, E.M., ... 1876.
Professor Mining and Metallurgy, Ohio State University, Columbus, O.
Lowndes, William Shepherd, Ph.B., ... 1890.
42 Sherman Place, Jersey City, N. J.
Lucas, G. L., C.E., ... 1898.
Kingsbridge, N. Y.
Luttgen, Eberhard, Ph.B. . . . . 1884.
Wyncote P. O., Pa.
McClelland, J. B., Ph.B., ... 1897.
2 West 47th Street, New York City.

McLellan, H., B.S., ... 1898.
108 East 18th Street, New York City.
McCulloh, E. A., Ph.B., ... 1878.
Glencoe, Md.
McDowell, Frederick H., E.M., ... 1872.
Address unknown.
McIlvain, Alexis Reed, Ph.B., ... 1888.
Architect, 48 Exchange Place, New York City.
McKee, H. S., E.M., ... 1893.
Los Angeles Terminal Railway Company, Los Angeles, Cal.
McKilay, James Buell, E.M., ... 1892.
108 West 79th Street, New York City.
McKleroy, William Henry, Met. Eng., ... 1892.
Cashier Anniston National Bank, Anniston, Ala.
McLean, J. M., E.E., ... 1897.
204 West 36th Street, New York City.
McNeil, Charles R., Ph.B., ... 1894.
Litchfield, Conn.
MacGahan, Paul, E.E., ... 1896.
523 Kelly's Avenue, Wilkinsburg, Pa.
McClur, W. J., E.E., ... 1898.
259 West 52d Street, New York City.
MacGregor, Donald, Ph.B., ... 1896.
1118 Madison Avenue, New York City.
MacMullen, C. W., E.E., ... 1897.
52 West 161st Street, New York City.
MacTague, John J., E.M., ... 1883.
Address unknown.
Maben, J. C., Jr., E.E., ... 1897.
279 Lexington Avenue, New York City.
Macy, V. E., Ph.B., ... 1893.
18 West 53d Street, New York City.
Madden, J. H., C.E., ... 1897.
308 West 30th Street, New York City.
Magalhaes, G. W., E.E., ... 1897.
Flatbush, New York.
Maghee, John Holme, A. B., A.M., C.E., ... 1876.
Cayuga Lake Ice Line, Rochester, New York, and 29 East 32d Street, New York City.
Mahl, J. Thomas, C.E., ... 1891.
G. H. and S. A. R. R. Co., Houston, Texas.
Manheims, L. R., E.E., ... 1897.
164 East 79th Street, New York City.
Mann, C. R., A.B., A.M., ... 1897.
Address unknown.
Mann, Horace Borchsenius, Ph.B., ... 1890.
Orange, N. J.
Mapes, Charles Halstead, Ph.B., ... 1889.
60 West 40th Street, New York City.
Matthews, Charles Thompson, Ph.B., ... 1889.
Architect, Elm Park, Norwalk, Conn.

Matthew, W. D., Ph.B., ... 1892.
St. John, M. B., Canada.

Matsui, Nawokichi, Ph.B., Ph.D., ... 1878.
Agricultural College, Konaba, Tokio, Japan.

Mattison, Joseph Godley, Ph.B., ... 1880.
Real Estate and Insurance Broker, 20 West 14th Street, New York City.

Meikleham, Thomas Mann Randolph, C.C., ... 1890.
Columbia Electrical Supply Co., 339 Fourth Avenue, New York City.

Merwin, H. J., E.M., ... 1879.
Middlesborough, Ky.

Mesa, Antonio Esteban, C.E., ... 1882.
Address unknown.

Mears, George K., E.E., ... 1894.
Elizabeth, N. J.

Metzger, Arthur, Ph.B., ... 1896.
43 East 72d Street, New York City.

Milliken, G. F., E.M., ... 1879.
Union League Club, New York City.

Mitchell, H. B., ... 1898.
164 Washington Place, Brooklyn, N. Y.

Moeller, Rudolph, Ph.B., ... 1887.
336 West 29th Street, New York City.

Monell, Ambrose, Jr., E.E., ... 1896
43 Lafayette Place, New York City.

Montgomery, H. P. A., Ph.B., ... 1896.
1189 Madison Avenue, New York City.

Morgan, J. L., Ph.B., ... 1888.
47 Fulton Street, New York City.

Morewood, George Barrow, E. M., Ph.D., ... 1878.
156 West Seventy-sixth Street, New York City.

Morewood, Henry Francis, E.M., Ph.D., ... 1876.
Importer, Box 2088, New York City.

Mortimer, L. N., E.E., ... 1898.
54 West Twenty-first Street, New York City.

Morris, B. W., Jr., Ph.B., ... 1896.
33 West Forty.second Street, New York City.

Morse, George T., Ph.B., ... 1896.
613 Carleton Avenue, Brooklyn, N. Y.

Munoz del Monte, A.C., C.E., Ph.D., ... 1888.
328 Chestnut Street, Philadelphia, Pa.

Munroe, M., E.E., ... 1894.
Address unknown.

Murphy, J. G., E.M., C.E., ... 1877.
Grand Union Hotel, New York City.

Murray, George, E.M., ... 1874.
235 West Twenty-third Street, New York City.

Murchison, K. M., Jr., Ph.B., ... 1894.
46 West Fifty-seventh Street, New York City.

Nambu, Kingo, E.M., ... 1878.
Nagasaki, Japan.

Nettre, L. R., E.M., ... 1869.
26 Coventry Street W., London, England.
Necarsulmer, Edward, Ph.B., ...
109 East 70th Street, New York City.
Neftel, Knight, C.E., Ph.D., ... 1879.
115 Broadway, New York City.
Newberry, S. B., E.M., Ph.D., ... 1878.
Sandusky Portland Cement Co., Sandusky, Ohio.
Newhouse, E. L., E.M., ... 1886.
Mgr. Philadelphia Smelting Company, Denver, Colo.
Newton, T. M., Ph.B., ... 1893.
40 West 75th Street, New York City.
Newman, M. L., E.E., ... 1898.
107 East 90th Street, New York City.
Neymann, Percey, Ph.B., Ph.D., ... 1881.
Chemist and Assistant Superintendent, 36 Michigan Street, Cleveland, O.
Nicholas, Harry Parmelee, E.M., ... 1887.
Hotel St. George, 49 East Twelfth Street, New York City.
Noble, Charles Milton, E.M., ... 1879.
Manager Ruttan Mfg. Co., Anniston, Ala.
Noble, Louis S., E.M., ... 1885.
Address unknown.
Norris, D. H., E.M., ... 1877.
123 West Twenty-fourth Street, New York City.
O'Reardon, I., C.E., ... 1897.
229 East Eighteenth Street, New York City.
Oakes, J. C., B.S., Ph.B . . . . . 1893.
423 West Twenty-first Street, New York City.
Oseranski, Isaac Henry, C.E., ... 1889.
Address unknown.
Otto, C. L., B.S., ... 1898.
885 Bushwick Avenue, Brooklyn, N. Y.
Owen, F. N., E.M., ... 1878.
115 East 45th Street, New York City.
Owens, Robert Bowie, E.E., ... 1892.
Professor Elect. Engineering, University of Nebraska, Lincoln, Neb.
Oxnard, James Guerrero, Ph.B., ... 1883.
Norfolk, Neb.
Painter, Robert K., E.M., ... 1896.
New York and Honduras Rosario Mining Co., San Juarisita, Rep. du Honduras, Central America.
Palmer, Cortlandt Edward, E.M., ... 1879.
Colorado Springs, Colo.
Palmer, George A., C.E., ... 1896.
922 Fifth Avenue, New York City.
Parmly, Charles Howard, B.S., E.E. . . . . 1892.
344 West Twenty-ninth Street, New York City.
Parsons, H. A., C.E. . . . . 1894.
South Norwalk, Conn.
Parsons, George H., E.M., ... 1868.
Colorado Springs, Colo.

Pazos, Vincent Felix, E.M., ... 1878.
Address unknown.

Pearis, C. F., E.M., ... 1884.
B9x 374, Helena, Mont.

Pearce, R., Ph.D.. . . . . 1890.
Address unknown.

Peck, T. B., Jr., E.E.. . . . . 1898.
111 East Thirty-fourth Street, New York City.

Pederson, F. M., B.S., E.E., ... 1893.
327 West Thirty-fourth Street, Mew York City.

Pelton, H. C., Ph.B., ... 1890.
No. 1 Mansion Avenue, New York City.

Penoff, Joel, C.E., ... 1896.
244 East Broadway, New York City.

Perry, Nelson W., E.M., ... 1878.
Editorial Staff 'Electrical World," New York City.

Perry, Charles L., E.E., ... 1896.
14 Hampden Street, New York City.

Pfister, Philip Charles, E.M., ... 1875.
Address unknown.

Pierce, Harry Nelson, E.M. . . . . 1885.
Address unknown.

Platt, Charles Slason, E.M., ... 1868.
Assayer, 21 and 31 Gold Street, New York City.

Pomeroy, W. A., E.M., ... 1893.
Oswego, Oregon.

Pope., J. R., Ph.B., ... 1894.
111 East Twenty-fifth Street, New York City.

Portuondo, José, C.E., ... 1890.
San Basilio, Alta 28, Santiago, Cuba.

Post, A. Van Zo, C.E.. . . . . 1889.
45 Wall Street, New York City.

Post, R. B., Ph.B., ... 1893.
Elizabeth, N. J.

Post, William Stone, Ph.B., ... 1890.
Bernardsville, N. J.

Potter, William B., A.B., E.M. . . . . 1883.
1225 Spruce Street, St. Louis, Mo.

Powers, Cornelius Van Vorst, Ph.B. . . . . 1882.
Assistant Engineer Aqueduct, Katonah, N. Y.

Primelles, José Alejandro, C.E., ... 1887.
Mercedes 23, Puerto Principe, Cuba.

Prince, A. D., C.E., ... 1893.
30 West Forty-seventh Street, New York City

Proctor, William Ross, E. M., ... 1884.
43 and 45 Sixth Avenue, Pittsburg, Pa.

Provost, F. A., C.E., ... 1893.
Jerome, Arizona.

Provost, George, Ph.B., ... 1889.
Architect, 24 Highland Terrace, Orange, N. J.

Radford, William Helsham, E.M., ... 1877.
Lydenburgh Gold Mining Co., Limited, Manchester, Eng.
Raisman, A. F., C.E., ... 1898.
50 Wallace Street, Newark, N. J.
Ralph, H. P., C.E., ... 1897.
2305 Munroe Avenue, New York City.
Randolph, Edmund, Ph.B., ... 1883.
E. & C. Randolph, 7 Nassau Street, New York City, also Knickerbocker Club.
Rappold, G. W., Ph.B., ... 1897.
750 Flushing Avenue, Brooklyn, N. Y.
Raymer, George Sharp, A.B., E.M., ... 1881.
Mine Superintendent, Idaho Springs, Colorado, and 63 Seventh Avenue, Brooklyn, N. Y.
Raymond, Alfred, Ph.B., ... 1891.
123 Henry Street, Brooklyn, N. Y.
Raymond, Wm. O., Ph.B., ... 1896.
31 East Eighty-second Street, New York City.
Raynor, R., Ph.B., ... 1889.
114 East Forty-fifth Street, New York City.
Reed, William Bell Stephen, E.M., ... 1879.
Helena, Mont.
Rees, B. F., E.M., ... 1874.
Chattanooga, Tenn.
Reese, William W., A.B., E.E., ... 1892.
New Hamburg, N. Y.
Regan, George W., E.E., ... 1896.
352 Degraw Street, Brooklyn, N. Y.
Rennard, John C., E.E., ... 1894.
302 West Seventy-third Street, New York City.
Restrepo, C. C., E.M., C.E., ... 1887.
Medellin, Rep. of Col., South America.
Reyna, J. E., E.E., ... 1898.
The Elmer, Morningside Avenue, New York City.
Reynolds, M., A.B., Ph.B., ... 1893.
98 Columbia Street, Albany, N. Y.
Riederer, E. J., Ph.B., ... 1897.
145 West Ninty-fourth Street, New York City.
Richardson, J. C., E.M., C.E , ... 1883.
Address unknown.
Richmond, William Thomas, Ph.B., ... 1881.
68 Thomas Street, New York City.
Ridsdale, T. W., E.M., ... 1883.
39 Cortlandt Street, New York City.
Riedel, A. E., M.E., ... 1896.
146 Delancey Street, New York City.
Riggs, Geo. Washington, Ph.B., ... 1871.
Summit, N. J.
Rittenhouse, Charles T., E.E., ... 1894.
247 West 138th Street, New York City.
Roberts, Arthur Carr, E.M., ... 1881.
Address unknown.

Roberts, Gracie Sayre, E.M., C.E., ... 1871.
Sewer Bureau, Dept. City Works, Brooklyn, N. Y.
Robertson, Kenneth, E.M., ... 1868.
General Manager West Superior Iron and Steel Co., W. Superior, Wis.
Robertson, Richard Spotswood, Jr., E.M., ... 1871.
Jackson, Minn.
Robinson, F. G., E.E., ... 1893.
Superintendent Amsterdam Street Railway, Amsterdam, N. Y.
Robinson, Henry Alvord, Ph.B., ... 1880.
Lawyer, 150 Broadway, New York City.
Rogers, Charles Louis, E.M., C.E., ... 1877.
823 Broad Street, Chattanooga, Tenn.
Rood, R. G., Ph.B., ... 1884.
Care Professor O. N. Rood, Columbia University, New York City.
Ross, William Coleman, C.E., EM., ... 1876.
Address unknown.
Rutherford, Lewis Hopkins, E.M., ... 1887.
Franklin, Pa.
Sanders, Wilbur Edgerton, E.M., ... 1885.
Mine Supt., Ewing and Seventh Avenue, Helena, Mont.
Sands, F., A.B., Ph.B., ... 1882.
Box 1172, Butte, Mont.
Savage, Seward Merrill, C.E., ... 1892.
2260 Pacific Street, Brooklyn, N. Y.
Sawyer, Charles Pike, Ph.B., ... 1881.
Sporting Editor *Evening Post*, New York City.
Sayers, J. H., C.E., ... 1897.
456 Classon Avenue, Brooklyn, N. Y.
Schlecht, W. W., C.E., ... 1897.
446 East 57th Street, New York City.
Schroter, G. A., E.M., ... 1893.
Box 877, Denver, Colo.
Seligman, J. G., E.M., ... 1887.
506 West 143d Street, New York City.
Sergeant, E. M., E.E., ... 1896.
Summit, N. J.
Serber, David C., C.E., ... 1896.
271 East Broadway, New York City.
Shack, Albert P., E.M., ... 1868.
108 East Twenty-fifth street, New York City.
Shire, Edward I., Ph.B., ... 1896.
109 East Sixtyfi-rst Street, New York Clty.
Shope, Henry Brengle, Ph.B., ... 1885.
19 West Thirty-second Street, New York City.
Shrady, Chas. D., ... 1895.
Continental Match Co., Passaic, N. J., and 8 East 66th Street, New York City.
Skidmore, Samuel Tredwell, A.B., Ph.B., ... 1889.
71 West Fiftieth Street, New York City.
Slichter, W. I., E.E., ... 1896.
127 West Fifty-eighth Street, New York City.

Sloane, Thomas O'Connor, A.B., A.M., E.M., Ph.D., ... 1872.
South Orange, N. J.

Small, Franklin Maurice, Ph.B., ... 1889.
Architect, 199 Second Avenue, New York City.

Smeaton, William Henry, C E., E.M., ... 1877.
15 Horatio Street, New York City.

Smedberg, Henry Ashton, A.B., C.E., ... 1884.
347 Fifth Avenue, New York City.

Smith, H. A., Ph.B., ... 1893.
460 West Forty-fourth Street, New York City.

Smith, Maxwell, C.E., ... 1880.
Adon Smith, 8 Bridge Street, New York City.

Smith, O. B., Jr., Ph.B., ... 1897.
Morristown, N. J.

Smyth, Roland Mulvill, E.M., C.E., ... 1877.
452 Produce exchange, New York City. 1879 to date, banker and broker.

Speyers, Clarence Livington, Ph.B., ... 1884.
Associate Professor Chemistry, Rutgers College, New Brunswick, N. J.

Stallnecht, Frederick, E.M., ... 1868.
Editor, 11 Bond Street, New York City.

Stander, Isaac, C.E., ... 1897.
315 East 77th Street, New York City.

Staunton, J. A., Jr., ... 1887.
Care Rev. John A. Staunton, 5 Seymour Street, Syracuse, N. Y.

Starr, Henry Fowler, Ph.B,, ... 1879.
91 Mt. Pleasant Avenue, Newark, N. J.

Steers, James Rich, Ph.B., ... 1890.
10 East 38th Street, New York City.

Stern, Henry, Ph.B., ... 1896.
230 East 69st Street, New York City.

Steinam, J. L., Ph.B., ... 1894.
31 West 95th Street, New York City.

Stevens, Alexander, C.E., ... 1887.
No. 1 Newark Street, Hoboken, N. J.

Stewart, Hunter, E.M., ... 1875.
Address unknown.

St. John, Thomas Matthew, Met. Eng., ... 1890.
New York City.

Stoughton, Arthur Alexander, Ph.B., ... 1888.
1665 Washington Avenue, New York City.

Stoughton, Charles William, C.E., ... 1889.
1665 Washington Avenue, New York City.

Stout, J. S., Jr., A.B., E.E., ... 1897.
35 East 67th Street, New York City.

Stratton, Alex., E.E., ... 1894.
2013 Fifth Avenue, New York City.

Strieby, William, A.M., E.M., ... 1878.
Professor of Metallurgy and Assaying, Colorado College, Colorado Springs, Colo.

Strout, William Allen, Ph.B., ... 1891.
366 Carlton Avenue, Brooklyn, N. Y.

Suydam, John Richard, Jr. E.M., ... 1879.
14 East 41st Street, New York City.
Tachan, Wm. G., Ph.B., ... 1896.
Louisville, Ky.
Taylor, A. S. G., Ph.B., ... 1897.
205 West 57th Street, New York City.
Temple, S. J., Ph.B., ... 1892.
Address unknown.
Tennille, George F., Ph.B., ... 1894.
Central Lard Company, 519 West 33d Street, New York City.
Thomas, Franz Charles, Ph.B., ... 1891.
Address unknown.
Thomas, W. S., E.M., ... 1898.
417 W. 117th Street New York City.
Thompson, H. C., C.E., ... 1886.
Lorillard Place, New York City.
Thompson, Milton Strong, Ph.B., ... 1875.
Chemist, Newburyport, Mass.
Thompson, S. C., A.B., E.M., ... 1893.
Grass Valley, Nevada Co., Cal.
Thorne, William Lincoln, Ph.B., ... 1890.
63 High Street, Yonkers, N. Y.
Tibbals, R. G., C.E., ... 1897.
148 Milton Street, Brooklyn, N. Y.
Tilden, G. C., C.E., ... 1876.
Reefton, New Zealand.
Tilghman, H. A., E.M., ... 1893.
Sansleto, Cal.
Toch, Max B., Ph.B., ... 1896.
34 West Ninety-second Street, New York City.
Tompkins, J. A., Ph.B., ... 1894.
Address unknown.
Totten, George Oakley, Jr., Ph.B. (1892), ... 1891.
62 North Eleventh Street, Newark, N. J.
Toucey, Donald Butler, LL.B., E.M., ... 1882.
743 Madison Avenue, New York City.
Towart, James, C.E., ... 1892.
Box 296, Peekskill, N. Y.
Tower, A. E., E.M., ... 1883.
Poughkeepsie, N. Y.
Trapote, P., ... 1898.
130 West Twenty-ninth Street, New York City.
Trowbridge, Samuel Breck Parkman, A.B., Ph.B., ... 1886.
Architect, 7 East Forty-sixth Street, New York City.
Tudor, W. J., A.B., E.M., ... 1898.
240 West 121st Street, New York City.
Tubby, J. T., Jr., Ph.B., ... 1896.
67 Willow Street, Brooklyn, N. Y.
Tucker, Allen, Ph.B., ... 1888.
80 Washington Square E., New York City.

Tucker, John Henry, Ph.B., Ph.D., ... 1875.
Globe Smelting and Refining Company, Denver, Colo.
Tuttle, W., Ph.B., ... 1893.
520 Summer Avenue, Newark, N. J.
Tuttle, William W., E.M., ... 1867.
Springfield, Mo.
Uhlig, William C., Ph.B., ... 1896.
229 East Twelfth Street, New York City.
Value, B. R., E.M., ... 1884.
Address unknown.
Van Benthuysen, Boyd, Ph.B., ... 1896.
Albany, N. Y.
Van Blarcom, E. C., C.E., ... 1876.
Hidalgo, Mexico.
Van Boskerck, Robert Ward, E.M., ... 1877.
Artist, 58 West Fifty-seventh Street, New York City.
Van Brunt, Arthur Hoffman, Ph.B., ... 1886.
Architect, 54 Wall Street, New York City.
Van Dyck, Edwin, Ph.B., ... 1888.
1080 Dean Street, Brooklyn, N. Y.
Van Ingen, Dudley Arthur, Ph.B., ... 1892.
135 Henry Street, Brooklyn, N .Y.
Van Lennep, David, E.M., ... 1868.
Auburn, Placer County, Cal. Fruit ranch.
Van Vlech, Joseph, Jr., Ph.B., ... 1896.
Montclaire, N. J.
Van Wagenen, T. F., E.M., ... 1870.
1508 Fillmore Street, Denver, Colo.
Vanderbilt, W. D., C.E., ... 1894.
44 Monroe Place, Brooklyn, N. Y.
Vatable, J. J., Ph.B., ... 1894.
89 Water Street, New York City.
Volckening, G. J., Met.E., E.M., ... 1888.
38 Clinton Street, Brooklyn, N. Y.
Wainwright, Richard Tighe, C.E., ... 1890.
Rye, N. Y.
Waldenberger, C. A., Ph.B., ... 1897.
155 East Thirty-seventh Street, New York City.
Wallace, William J., Ph.B., ... 1886.
Whitestone, N. Y.
Wallbridge, Frederick Kidder, E.M., ... 1884.
37 Ninth Avenue, Brooklyn, N. Y.
Walker, Joseph, Jr., C.E., ... 1880.
112 East Thirty-seventh Street, New York City.
Wanier, Albert George, Ph.D., ... 1882.
Kreisherville, Staten Island, N. Y.
Ward, Norbert Reillieux, E.M., ... 1882.
Morgan Furn. Co., 1180 Broadway, New York City.
Ware, F. B., Ph.B., ... 1894.
1285 Madison Avenue, New York City.

Warren, Charles Peck, Ph.B., A.M. (1892), ... 1890.
386 Clifton Place, Brooklyn, N. Y.

Warren, Lloyd, Ph.B., ... 1891.
520 Fifth Avenue, New York City.

Waterbury, Cornelius Reed, C.L., C.E., LL.B., ... 1877.
Lawyer, 45 Broadway, New York City.

Wafers, George Safford, Ph.B., ... 1889.
Architect, Andrews, Waters & Sherwin, 42 W. Forty-third St., N. Y. City.

Webb, Henry Walter, E.M., LL.B., ... 1873.
Third Vice-President, N. Y. C. & H. R. R. R., and 15 West Forty-seventh Street, New York City.

Wedekind, E. H., Ph.B., ... 1888.
Spokane, Wash.

Wells, D. C., E.E., A.B., ... 1896.
109 Willow Street, Brooklyn, N. Y.

Wels, Paul O., E.M., B.S., ... 1887.
Boston & Montana Co., Great Falls, Mont.

Welsh, Howard Farrington, E.M., ... 1890.
Mingo Mountain Coal and Coke Co., Hartranft, Tenn.

Werner, Henry Clay, Ph.B., ... 1892.
120 E. Sixty-fifth St., New York City.

Wertheimer, Lewis, Ph.B., ... 1887.
Allegheny City, Pa.

Wetmore, Edwin Atwater, E.M., ... 1875.
Iron Merchant, Marquette, Mich.

Wheatley, Joseph Yendes, C.E., ... 1886.
Cold Spring, N. Y.

White, Lazarus, C.E., ... 1897.
14 East 120th Street, New York City.

Whitman, Edmund Pineo, E.M., ... 1885.
Hillside Avenue, Englewood, N. J.

Williams, Frederick Harrison, E.M., ... 1874.
Riverside Iron Works, and 34 Virginia Street, Wheeling, W. Va.

Williams, G. W., E.M., C.E. . . . . 1879.
323 Genesee Street, Utica, N. Y.

Wilson, Clarence Edgar, Ph.B., ... 1886.
Address unknown.

Windecker, Clifton Nicholas, C.E., ... 1892.
33 Sidney Place, Brooklyn, N. Y.

Windolph, A. P., Ph.B. . . . . 1892.
Address unknown.

Windreple, A. P., Ph.B., ... 1892.
Address unknown.

Witherel, Chas. S., Met.E., ... 1896.
Greenwich, Conn.

Wreff, H. H., C.E., ... 1898.
548 West 148th Street, New York City.

Wood, George E., E.M., Ph.B., ... 1884.
Architect, 63 William Street, New York City.

Woodruff, George W. L., Ph.B., E. E., ... 1896.
27 East Twenty-second Street, New York City.

Wright, Albert Allen, A.M., Ph.B., ... 1875.
Professor of Geology and Natural History, Oberlin College, Oberlin, Ohio.

LIST No. 4.

Contains the names of Members of the Alumni Association classified territorially by their professional address. Those not Members of the Association are not included by reason of the uncertainty as to address of such persons.

(Revised to January, 1899.)

GEOGRAPHICAL SUMMARY.

Showing the Counties and States in which the Association is represented by members who reside therein, and the State or country in which they reside. The local address of members will be found in List No. 2, in which their names are arranged alphabetically.

UNITED STATES.

State or Territory.	No. of Members.	State or Territory.	No. of Members.
Alabama	1	Minnesota	3
Arizona	2	Missouri	8
California	11	Montana	9
Colorado	14	Nevada	1
Connecticut	2	New Jersey	29
Delaware	1	New York	336
District of Columbia	10	North Carolina	2
Florida	1	Ohio	4
Illinois	11	Oregon	1
Idaho	1	Pennsylvania	23
Indiana	3	Rhode Island	1
Indian Territory	1	South Carolina	1
Iowa	1	South Dakota	1
Kansas	1	Tennessee	4
Louisiana	1	Texas	3
Maryland	2	Utah	5
Massachusetts	6	Wisconsin	1
Michigan	4	Washington	2
Total, United States			507

FOREIGN COUNTRIES.

State or Territory.	No. of Members.	State or Territory.	No. of Members.
Australia	1	Japan	1
Brazil	1	Mexico	11
Canada	7	Nicaragua	1
Cuba	4	Oceanica	1
Eastern Siberia	1	Peru	1
Great Britain (England)	2	Republic of Colombia	1
Guatemala	1	South African Republic	6
Honduras	1		
Total, Foreign Countries			40

Total, United States	507
Total, Foreign Countries	40
Present Address Unknown	3
Total Membership	550

Alabama.

Tucaloosa.—S. Friedman.

Arizona.

Congress.—W. F. Staunton.
Pearce.—G. F. Reckhart.

California.

Bodie.—R. G. Brown.
Grass Valley.—G. F. Sherman.
Los Angeles.—H. A. Titcomb.
Palo Alto.—L. R. Lenox.
San Francisco.—L. C. Easton, E. F. Haas, N. B. Knox, D. E. Melliss, R. A. Parker, E. A. Wiltsee.
Selby.—E. N. Engelhardt.

Colorado.

Denver.—H. V. F. Fuhrman, M. W. Iles, C. F. Lacombe, B. B. Lawrence, T. B. Stearns.
Durango.—E. J. H. Amy.
Leadville.—Geo. B. Lee, E. H. Messiter.
Pueblo.—F. P. Bayles, K. E. Eilers, R. D. Rhodes.
Rico.—L. H. Barnet.
Silverton.—M. B. Holt, E. W. Miller.

Connecticut.

Bridgeport.—F. I. Cairns.
Collinsville.—W. Hill.
Middletown.—H. C. Sherman.
Riverside.—C. M. Lowther.

Delaware.

Wilmington.—H. G. Haskell.

District of Columbia.

Washington.—E. C. Barnard, Marcus Benjamin, E. M. Douglas, A. W. Dow, H. Hollerith, F. W. Tower, W. H. Weed, B. Willis, H. M. Wilson.

Florida.

Key West.—C. E. Rodgers.

Illinois.

Aurora.—O. F. Pattberg.
Carthage.—J. C. Ferris.
Chicago.—E. G. Barratt, Edward Gudeman, H. L. Hollis, S. B. Peck, F. B. F. Rhodes, G. S. Rice, W. H. Van Arsdale, L. Wampold.
Joliet.—C. L. Miller.

Idaho.

Moscow.—E. Goodwin.

Indiana.

Elkhart.—E. L. Kurtz.
Lafayette.—E. M. Blake.

Indian Territory.

Hartshorn.—E. Ludlow.

Iowa.

Clinton.—R. Adams.

Kansas.

Argentine.—A. S. Dwight, H. Garlichs.

Louisiana.

New Orleans.—G. S. Eastwick.

Maryland.

Baltimore.—H. A. Prosser, A. L. Walker.

Massachusetts.

Boston.—I. N. Evans, C. R. Harte.
Cambridge.—J. A. Noyes.
Holyoke.—L. J. Powers, Jr.
New Bedford.—N. Hathaway, W. F. Williams.

Michigan.

Houghton.—H. D. Conant, R. M. Edwards, F. McM. Stanton.
Vulcan.—W. Kelley.

Minnesota.

Minneapolis.—W. R. Appleby, F. W. Denton, L. Whiting.

Missouri.

Carthage.—A. O. Ihlseng.
De Soto.—O. M. Munroe.
Joplin.—I. S. Lydecker.
Poplar Bluff.—E. A. Harris.
St. Louis.—G. Sessinghaus, E. Starek, A. Thacher, H. A. Wheeler.

Montana.

Bozeman.—F. W. Traphagen.
Butte.—F. Klepetko, B. R. Putnam, F. Sands.
Helena.—H. M. Cole, J. R. Parks.
Smelter.—A. F. Emrich, P. A. L. Mannheim, F. M. Smith.

Nevada.

Delamar.—R. Nichols.
Gold Creek.—Frank Hamilton.

New Jersey.

Amperé.—P. A. Bates.
Boyonne.—C. P. Bleecker.
Closter.—Chas. H. Eckerson.
Dover—F. A. Canfield.
Fort Lee.—C. G. Massa.

Glen Ridge.—N. Butler.
High Bridge.—C. LeBoutillier.
Jersey City.—W. F. Downs, Chas. Drasel, C. E. Graff, R. H. Vondy.
Morristown.—J. R. Brinley, J. P. Pennington, J. F. Randolph, E. Waller.
New Brunswick.—A. H. Chester.
Newark—H. G. Atha, C. A. Colton, Jos. Lowenstein, E. Merz, H. M. Murphy, G. C. Stone, F. Vanderpoel, W. Wiener.
Passaic.—E. W. Guiterman.
Paterson.—J. H. Clark.
Perth Amboy.—D. F. Haasis, A. F. Schneider.
Princeton.—H. B. Cornwall.
Trenton.—J. H. Janeway.

New York

Albany.—F. J. H. Merrill.
Brooklyn—R. L. Allen, G. W. Behrman, S. D. Benoliel, R. T. Betts, D. D. Book, E. P. Clark, F. D. Dodge, W. L. Dusenberry, L. G. Engle, E. P. Folger, S. A. Goldschmidt, J. S. Langthorn, F. C. A. Meisel, J. H. Merritt, W. M. Meserole, H. H. B. Meyer, J. Middleton, J. Nesmith, T. S. Perkins, F. E. Pierce, A. J. Provost, C. B. Rowland, G. Rowland, R. Seldner, W. W. Share, E. Skinner, G. C. Southard, G. A. Tibbals, S. G. Tibbals, W. L. Tyler, W. B. Vanderbilt, H. V. Walker.
Buffalo.—E. L. Ingram.
Cazenovia.—H. Burden, 2d.
Clinton.—C. H. Smyth, Jr.
Flatbush.—E. R. Von Nardroff.
Flushing.—A. M. Ryon
Irvington-on-Hudson.—G. H. Casamajor.
Ithaca.—H. Ries.
Jamaica.—R. D. Godley, Jr.
Jordan.—D. J. Greene.
Laurel Hill.—W. C. Ferguson, H. K. Masters.
Locust Valley.—L. H. Vaile.
New Brighton.—W. B. Johnstone.
New Rochelle.—L. P. De Luze.
New York City.—G. H. Abeel, E. K. Adams, S. W. Andrews, W. C. Andrews, L. A. Ansbacher, A. Anthony, P. J. Austen, W. M. Baldwin, J. H. Banks, A. C. Beatty, Chas. A. Bechstein, A. L. Beebe, W. L. Benedict, Geo. Berry, W. G. Berry, J. Binion, J. R. Bien, R. R. Bishop, A. Black, Francis Blossom, M. T. Bogert, O. Bedelsen, W. Boecklin, Jr., S. Bookman, R. E. Booraem, R. C. Boyd, N. L. Britton, H. D. Brewster, C. R. Buckley, A. L. Burns, W. G. Burns, Wm. H. Burr, W. P. Butler, A. Calman, E. P. Casey, K. L. Caswell, J. P. Cauldwell, Chas. F. Chandler, J. P. Channing, E. D. Church, J.

A. Church, C. M. Clark, Edmund Clark, G. H. Clark, T. R. Coffin, F. A. Cokefair, J. T. Conover, Fredk. Coykendall, S. H. Crampton, F. B. Croker, A. R. Cushman, E. H. Daly, H. G. Darwin, C. H. Davis, J.W. Davis, J. A.Deghuee, A.F. Delafield, C. Derleth, Jr., C. H. Detwiller, W. B. Devereux, C. F. Dolan, J. S. Douglas, D. Le R. Dresser, I. W. Drummond, E. L. Dufourcq, E. K. Dunham, G. S. Eastwick, W. G. Eberhardt, T. Egleston, A. H. Elliott, W. Elliott, G. E. Fahys, P. Le R. Fearn, Geo. A. Ferguson, C. F. Ferrer, H. Feuchtwanger, W. Fisher, R. G. Foster, P. W. Foster, A. E. Foyé, J. W. Frank, W. H. Freedman, S. D. Gifford, A. C. Gildersleeve, C. B. Going, John Gordon, E. H. Gould, L. P. Gratacap, A. D. Granger, J. L. Greenleaf, L. N. Gross, H. S. Hadden, L. F. Haffen, A. W. Hale, R. W. Hall, A. P. Hallock, A. W. Hankinson, R. C. Hanson, G. E. Harding, G. M. Haskell, O. B. Hébert, A. M. Heinsheimer, H. H. Hendricks, J. M. Hewlett, W. E. Hildreth, L. W. Hildburg, E. H. Holden, A. Hollick, H. M. Howe, F. F. Hunt, F. R. Hutton, F. S. Hyde, H. St. J. Hyde, O. Jackson, D. M. Jacobs, S. J. Jacobs, F. H. Jobbins, C. H. Joüett, J. C. Kastner, J. F. Kemp, F. W. Kinsey, Burdett Kipp, G. T. Kirby, J. J. Koen, W. B. Kunhardt. J. H. Ladew, J. Lahey, D. G. Leary, G. Leary, E. J. Lederle, A. R. Ledoux, E. J. Levine, C. McK. Lewis, A. L. Levy, E. W. Libaire, A. Liebmann, Henry Lipps, Jr., W. P. Little, A. R. Livingston, L. B. Longacre, E. G. Love, F. R. Lord, Max Lowenthal, Frank Ludlam, Frank Lyman, L. McI. Luquer, T. T. P. Luquer, G. Lusk, R. S. McCaffery, J. B. McClelland, P. C. McIlhiney, C. F. McKenna, Alex. R. McKim, R. A. McKim, J. MacLay, H. S. MacKaye, Jas. MacLay, A. S. Mahony, R. E. Mayer, C. S. McLoughlin, A. J. Malukoff, L. Marie, E. W. Martin, L. T. Martin, L. F. Massa, J. A. Mathews, E. H. Miller, R. P. Miller, S. O. Hiller, E. J. Moeller, J. T. Monell, R. A. Monks, M. R. Montenegro, M. L. Mora, D. E. Moran, W. F. Morgan, R. K. Mosley, A. J. Moses, P. R. Moses, Robert Mulford, George Müller, H. S. Munroe, C. E. Munsell, William Newbrough, A. C. Nye, M. J. O'Connor, T. D. O'Connor, Charles Of, E. E. Olcott, Max Osterberg, A. McC. Parker, H. C. Parker, C. F. Parraga, Henry Parsons, W. B. Parsons, C. Q. Payne, Robert Peele, C. E. Pellew, C. P. Pengnet, S. Perkins, Geo. Perrine, W. Pistor, L. Pitkin, H. H. Porter, Jr., A. S. Post, W. E. Preston, J. L. Prince, J. C. F. Randolph, S. A. Reed, J. K. Rees, G. Renault, J. M. Rich, P. de P. Ricketts, T. W. Ridsdale, E. J. Riederer, Chas. Rodenburg, O. L. Rogers, O. N. Rood, P. Rupp, F. M. Rutherford, F. Ruttmann, E. E. Sage, G. C. Saunders, R. M. Schell, F. A. Schermerhorn, W. J. Schieffelin, J. L. Schroeder, C. H. Schumann, C. D. Searle, J. G. Seligman, John Seward, L. R. Shattuck, F. D. Sherman, H. T. Shriver, F. M. Simonds, A. Smith, F. P. Smith, L. Smith, W. A. Smith, W. A. Smith, Jr., W. F. Smith,

Jr., T. E. Snook, A. N. Spooner, J. H. Stewart, J. Struthers, W. H. Stuart, G. A. Suter, H. H. Sutro, J. L. Tatlock, J. B. Taylor, W. S. Thyng, W. H. Titus, E. De V. Tompkins, S. G. F. Townsend, G. F. D. Trast, G. R. Tuska, E. G. Tuttle, J. H. Van Amringe, W. Van B. Van Dyck, H. Van Sinderen, E. Van Volkenburgh, Jr., W. Vredenburgh, Jr., H. T. Vulte, J. H. Wainwright, Wm. R. Ware, W. H. Weeks, A. McM. Welsh, J. S. C. Wells, William Y. Westervelt, R. D. White, T. G. White, Wm. S. White, H. P. Whitlock, F. G. Weichmann, J. T. Williams, C. A. Wittmack, I. H. Woolson, E. L. Young.

Niagara Falls.—E. Z. Burns.
Northport.—W. H. Ingersoll.
North River.—F. C. Hooper.
Ontario.—E. M. Parrot.
Orangeburg.—S. R. Bradley, Jr.
Rhinebeck.—H. Pinkham.
Rochester.—H. P. Gillette.
Rondout.—Edward Coykendall.
Sing Sing.—W. S. Page.
Skineateilis.—F. M. Thomas.
Spuyten Duyvil.—E. M. Johnson, G. H. Johnson, I. B. Johnson.
Stirlengton.—Wm. C. Clark.
Syracuse.—H. B. Bellinger, E. C. Boerner, Jr.
Tarrytown.—F. N. Holbrook.
Westchester.—T. H. Harrington.
West Nyack.—George M. Miller.
White Plains.—R. E. Slade.
Whitestone.—D. W. Ward.
Yonkers.—S. W. Balch, W. D. Horne.

North Carolina.

Charlotte.—S. W. Cramer, G. B. Hanna.

Ohio.

Cincinnati.—David Forester.
Cleveland.—R. F. Jopling.
Loraine.—I. Menline.
Marietta.—C. G. Slack.

Oregon.

Portland.—F. Powell.

Pennsylvania.

Chambersburg.—T. J. Brereton.
Chester.—A. P. Van Gelder.
McKeesport.—T. M. Hopke, T. Tonnele.
New Boston.—J. E. Jones.

Osceola Mills.—G. McC. H. Good.
Philadelphia.—E. A. Congdon, R. Lahey, S. M. Lillie, Thomas Nolan, Charles Piez, A. Rosenthal.
Pittsburg.—W. L. McConway, R. G. G. Moldehnke, G. S. Page, C. A. Painter, G. E. Painter, G. Singer, Jr., G. H. Singer.
Scranton.—J. S. Beard.
South Bethlehem.—A. L. Colby.
Wilkesbarre.—Max Dobbins, R. V. A. Norris.

Rhode Island.

Providence.—Carl Barus.

South Carolina.

Oakley.—J. P. Carson.

South Dakota.

Lead.—A. J. Clark.

Tennessee.

Gallatin.—A. J. Lamb.
Isabella.—L. D. Huntoon.
Knoxville.—C. Van Deventer.
Tracy City.—J. J. Ormsbee.

Texas.

Eagle Pass.—W. Hollis.
El Paso.—D. W. Rickhardt.
Shafter.—W. S. Noyes.

Utah.

Jensen.—A. G. Johnson.
Sandy.—L. H. Norton.
Salt Lake City.—T. S. Mathis, R. H. Terhune, W. A. Wilson.

Wisconsin.

Hurley.—G. H. Abeel.

Washington.

Spokane.—J. L. Warner, E. H. Wedekind.

OUT OF THE UNITED STATES.

AFRICA.

South African Republic.

Germiston.—H. C. Mannheim.
Johannesburg.—B. P. Carter, T. H. Leggett, F. Roeser, E. D. Self, F. M. Watson.

ASIA.

Japan.

Tokio.—E. L. Young.

Eastern Siberia.

Vladivostock.—W. S. Davidson.

AUSTRALIA.

Kalgoorlie.—R. M. Raymond.

OCEANICA.

Island Celebes.

Gorontalo.—E. N. Van Cortlandt.

GREAT BRITAIN.

London.—B. C. Hinman, C. M. Rolker.

NORTH AMERICA.

Canada.

Nelson, B. C.—S. S. Fowler, E. C. Holden.
Montreal.—C. E. Gudewill, J. B. Porter.
Nova Scotia, Londonderry.—C. A. Meissner.
Parry Sound.—V. B. Buck.
Trail, B. C.—W. H. Aldridge.

SOUTH AMERICA.

Brazil.

Rio de Janeiro.—John Gordon.

Peru.

Casapalca.—A. W. Jenks.

Republic of Colombia.

Tumaco.—W. B. McKinley.

CENTRAL AMERICA.

Cuba.

Cardenas.—D. L. Clark.
Cienfuegos.—J. P. Ros.
Guantanamo.—L. F. Chibas.
Santiago de Cuba.—J. S. Cox.

Guatemala.

Quezaltenang.—J. F. Hawley.

Honduras.

Tegucigalpa.—E. C. Fiallos.

Mexico.

Chihuahua.—T. S. Austin.
City of Mexica.—V. M. Braschi, J. A. Navarro.
Coahuila.—C. S. Herzig.
Concepcion del Oro.—A. W. Lilliendahl, F. A. Lilliendahl.
Copala.—A. E. Swain.
Monterey.—E. Howe.
Pueblo.—T. W. Osterheld.
Romos.—R. B. Watson.
Tepezalta.—L. V. Emanuel.
Zacatecas.—R. Yrizar.

Nicaragua.

Greytown.—H. W. Durham.

CONSTITUTION

OF THE

ALUMNI ASSOCIATION

OF THE

SCHOOLS OF SCIENCE OF COLUMBIA UNIVERSITY.

Incorporated May, 1886, as The Association of the Alumni of the School of Mines of Columbia College. Name changed 1898.

ARTICLE I.

NAME.

The name of this Association is The Alumni Association of the Schools of Science of Columbia University.

ARTICLE II.

OBJECT.

The object of this Association is to promote the professional welfare of its members, and to strengthen the bonds of professional and social fellowship among the Alumni of the Schools of Science of Columbia University.

ARTICLE III.

MEMBERS.

SECTION 1. The membership of this Association shall be: I. Active. II. Associate. III. Honorary.

SEC. 2. All persons who have obtained degrees under the Faculties of Applied or Pure Science are eligible to active membership in this Association.

SEC. 3. Persons who have completed special courses under the

Faculties of Applied or Pure Science of Columbia University are eligible to associate membership in this Association.

SEC. 4. Persons eminent in science who are or have been connected with any of the Schools of Science of Columbia University are eligible to honorary membership in this Association.

SEC. 5. All members shall be elected to the Association by the Board of Managers.

SEC. 6. Honorary and associate members shall have all the privileges of active members, except those of voting and holding office.

ARTICLE IV.

DUES.

SEC. 1. The annual dues of active and associate members of this Association shall be three dollars, payable in advance on the first day of October in each year. Honorary members shall not be required to pay dues.

SEC. 2. Any member not in arrears may become a life member, and be relieved from further payment of annual dues by the payment, at any one time, of fifty dollars.

SEC. 3. Members one year in arrears may, after due notification, be dropped from the role, by vote of the Board of Managers, and shall then forfeit their rights and privileges in the Association until all arrears are paid, or until reinstated by the Board.

SEC. 4. Only those members not in arrears shall be entitled to vote or hold office.

ARTICLE V.

OFFICERS AND MANAGERS.

SEC. 1. The officers of the Association shall be a President, a Vice-President, a Treasurer and a Secretary. These officers and eight managers, to be elected as hereinafter provided, shall constitute the Board of Managers.

SEC. 2. The President, Vice-President, Treasurer and Secretary shall hold office for one year, and are eligible for re-election. The Managers shall hold office for two years, and are not eligible for re-election until one year after the expiration of their terms.

ARTICLE VI.

ELECTION OF OFFICERS AND MANAGERS.

SEC. 1. Before the last day of June of each year the President shall appoint a committee of five active members to nominate for election by the Association a President, a Vice-President, a Treasurer and a Secretary for the ensuring year, and four Managers to serve for the ensuing two years. The officers and managers must be residents of New York City or vicinity.

SEC. 2. The four managers shall be chosen with due regard to a representation of the Alumni of the Schools of Science upon the Board of Managers, and they shall be selected, one from each of the four groups into which the Board at a previous meeting in that year shall have divided in chronological order the classes which have graduated from the Schools of Science.

SEC. 3. The Nominating Committee must send in the nominations to the Secretary no later than October 15th of each year and such nominations shall be distributed within three weeks to the active members in the form of letter ballots, which must be signed and forwarded to the Secretary, and opened and counted by tellers at the annual meeting of the Association.

SEC. 4. In addition to such regularly appointed committee, any other five members, not in arrears, may constitute themselves an independent nominating committee, and may present to the Secretary before November 1st the names of such candidates as they may select. All the names of such independent nominees shall be placed upon the ballot list, with nothing to distinguish them from the nominees of the regular committee.

ARTICLE VII.

THE BOARD OF MANAGERS.

SEC. 1. The Board of Managers shall have the management of the affairs, funds and property of the Association, and it shall be the duty of the Board to see that the purposes of the Association are carried out according to its Constitution and By-Laws.

SEC. 2. The Board of Managers shall hold at least four regular meetings during each year, namely, in the months of January, May,

October and December. Other meetings shall be called by the President as may be required.

SEC. 3. The Board shall have power to fill any vacancy in its body by the election of an active member of the association from the group in which such vacancy occurs.

SEC. 4. A quorum shall consist of a majority of the whole Board.

ARTICLE VIII.

PRESIDENT:

It shall be the duty of the President to call and preside at all meetings of the Board of Managers of the Association; to appoint such standing and other committees of the Association as may be found necessary or convenient for the conduct of its work, and to perform such other duties as may devolve upon him by virtue of his office.

ARTICLE IX.

TREASURER.

It shall be the duty of the Treasurer to collect and have custody of all moneys and pay all bills of the Association, but no indebtedness shall be incurred unless approved by the Board of Managers. No bill shall be paid unless previously endorsed by the Secretary. The Treasurer shall present to the Board of Managers a written report upon the financial condition of the Association at the annual meeting in December. His accounts shall be audited by a committee of the Association appointed at the annual meeting.

ARTICLE X.

SECRETARY.

It shall be the duty of the Secretary to issue notices for all meetings of the Board of Managers and of the Association, to keep minutes of all meetings, to record names, addresses, and professional occupations of the members, and to perform such other duties as may be assigned to him by the Board of Managers.

ARTICLE XI.

DELEGATES TO ALUMNI COUNCIL OF COLUMBIA UNIVERSITY.

The Association shall be represented in the Alumni Council of Columbia University by delegates appointed by the Board of Managers, under such conditions and in such manner as the said Board shall prescribe.

ARTICLE XII.

MEETINGS.

SEC. 1. The annual meeting of the Association shall be held in the last week of December in each year, unless otherwise ordered by the Board of Managers.

SEC. 2. Regular meetings of the Association for social intercourse, or for the discussion of subjects of general or of professional interest, shall be held in the city of New York at such time and place as may be directed by the Board of Managers.

SEC. 3. Upon the written request of not less than ten active members, the President shall call a special meeting of the Association, which request, as also the notice of any special meeting, shall state the object for which the meeting is called.

SEC. 4. A quorum shall consist of thirty active members of the Association.

ARTICLE XIII.

SUSPENSION OR EXPULSION.

Any member of the Association may be suspended or expelled for misconduct in his relations to this Association or in his profession of proof thereof in such manner as may be prescribed hereinafter by By-laws.

ARTICLE XIV.

All interest in the property of the Association of persons resigning or otherwise ceasing to be members shall vest in the Association.

ARTICLE XV.

AMENDMENTS.

Any amendment to the Constitution must first be submitted in writing to the Board of Managers, and must be approved by a vote of two-thirds of the whole Board before presentation to the Association. Due notice of any proposed amendment shall be sent by the Board of Managers to every active member of the Association at least one month previous to the meeting at which such amendment is to be voted upon. A three-fourths' vote of the members voting, in person or by letter ballot, shall be necessary for the adoption of such proposed amendment.

BY-LAWS.

I. Unless otherwise directed the Order of Business at any meeting of the Association and its Board of Managers shall be as follows:

1. Reading of minutes of preceding meetings and action thereupon.
2. Report of the Board of Managers.
3. Report of officers.
4. Reports of standing committees.
5. Reports of special committees.
6. Elections and announcement of elections.
7. Unfinished business.
8. New business.
9. Appointment of committees.
10. Adjournment.

II. The absence of any member of the Board of Managers from two consecutive meetings of the same, of which he shall have been regularly notified, shall be considered as a resignation on the part of such member, unless the Board shall excuse such absence. The vacancy thus created shall be filled as provided for in the Constitution.

III. The Standing Committees of the Board of Managers shall be as follows:

1. On School of Mines Quarterly.
2. On Badges.
3. On Meetings of the Association.

All such committees, shall at the expiration of their terms of office, present written reports to the Board of Managers.

IV. The official organ of this organization shall be the SCHOOL OF MINES QUARTERLY, which will be furnished to all active and associate members.

V. The Standing Committee on Meetings shall arrange for regular meeetings of the Association in October and March of each year unless otherwise ordered by the Board of Managers..

VI. These By-Laws may be amended at any regular meeting of the Association, but only by a vote of two-thirds of those present, and provided that ten days' notice in writing of the proposed amendment shall have been given to the Board of Managers, and also that notice of the same shall have been given by the Secretary in the call for the meeting.

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THE school is well equipped with physical and chemical laboratories, in which the students are required to perform a complete set of experiments illustrative of their recitations in physics and general chemistry. A special laboratory is devoted to qualitative chemical analysis for advanced students.

In 1896, seventeen students from Woodbridge entered Columbia, of whom five took advanced standing, one entering the *second-year class* in Electrical Engineering. This year, 1898, fourteen of our students entered.

Four hundred Students of Columbia School of Mines have been instructed in the Woodbridge School. Also a large number have been prepared for Massachusetts Institute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Scientific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medical and Law Departments of Harvard, Yale, Columbia and Princeton.

An advanced course for older students prepares them to enter the second-year class.

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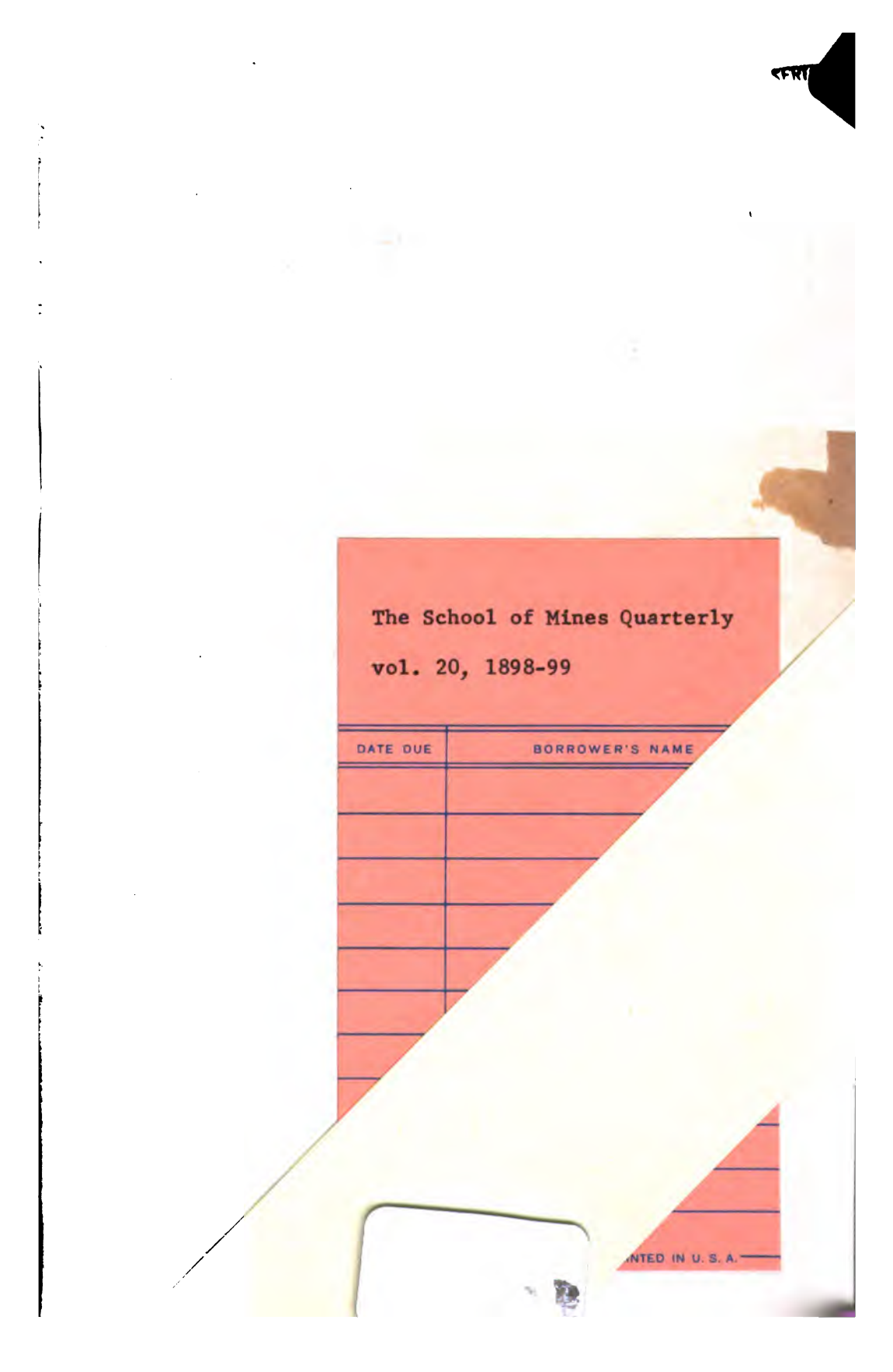
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